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Application of GPS Surveying for Extracting Highway's Horizontal Alignment

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Abstract

Korea is a small country with relatively large mountainous areas and has many difficulties from planning to completing one road. Maintaining a completed road presents even more difficulties. Presently, in estimating design elements, the result varies according to the engineer and there are many cases that question the reliability of the results.

Therefore, in this study, the alignment of highway was sampled using by the centerline path, the design elements of horizontal alignment were reduced by applying the Least Squares Method, and the accuracy was analyzed. By this method, IP, IA, R, ΔR and A-parameter were also determined.

By observing relatively long straight sections, the approximate values could be estimated, and particularly, the considerably accurate value of A-parameter was determined. This study, using the Least Squares Method, aims to contribute to the development of the alignment examination in frequent traffic accident regions.

Keywords : *GPS, Highway, Horizontal Alignment, Method of Least Squares, IP, R, A-parameter*

1. Introduction

Korea is a small country with relatively large mountainous areas and has many difficulties from planning to completing one road. Maintaining a completed road presents even more difficulties. Presently, in estimating design elements, the result varies according to the engineer and there are many cases that question the reliability of the results.[8)]

Therefore, this study aims to sample the road linear shape using the centerline path, to deduce the design elements of horizontal alignment using the Least Squares Method, and to analyze the accuracy.

2. Method of Least Squares for Sampling Alignment

It must first be decided how to use the sample observation value. As the sample observation value is not on a perfectly straight line, several different kinds of straight lines can be drawn through the displayed data. The line, which explains the data most appropriately, must be selected.

It is necessary to define which the most appropriate line is, to avoid subjective judgment in finding the sample regression line. It is logical to define the straight line, which has the smallest residual on the average as the most appropriate. The problem accompanied with this method is that though any residual never approaches 0 some residuals become plus and others become minus the sum of the residuals is always 0.

To avoid this problem, the straight line that has the smallest sum of squares of residuals is defined as the most appropriate line. This process is called the Least Squares Method.

The Least Squares Method is to reduce a straight line that minimizes the sum of squares of the distance from the observed datum to the straight line.

3. Data Collection and Arrangement

3.1 Selection of Investigation Area

The Local Road near Pusan and parts of curved

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Table 3.1. Horizontal Design of Investigation Area

Category		Nation al Road (NO. 35)	Local Road (Near Pusan)
Design Speed		80 (km/hr)	60 (km/hr)
IP	X	226378.0	189625.8
	Y	210095.0	218725.7
IA		49° 13′ 45.73″	48° 15′ 05.72″
A		175	0
R(m)		300	280
A		175	0
⊿R(m)		1.4459	0
S		1. Introduction102.0833	0

section in, National Road (NO. 35) were selected for investigation.

The Local Road is in the finishing stage, and the National Road (NO. 35) is expanded into a four-lane road both ways and has relatively fine horizontal alignment.

3.2 Data Collection and Arrangement

3.2.1 Elements of Observation Equipments

The characteristics of observation equipments are shown in Table 3.2.1.

Table 3.2.1. Characteristics of GPS Equipment

Category	GPS
Model	Topcon Turbo SII
Accuracy	10mm + 1ppm (horizontal) 20mm + 1ppm (vertical)

3.2.2 Collection of Observation Data

The chain distance was established and the center line path was measured by the KINEMATIC GPS measurement in the road extension section ○○ - ○○ near Pusan and parts of curved section in, National Road n.35. The chain distance was about 5m in the straight line section, the data acquisition interval according to the chain distance was set on the basis of 3 seconds, and the data collection interval was on the basis of 24 seconds.[3)]

Observation data are as Table 3.2.2, Table 3.2.3

Table 3.2.2. Observation data (A area)

No	X Coodinate (m)	Y Coodinate (m)	No	X Coodinate (m)	Y Coodinate (m)
1	189413.268	218735.811	23	189611.839	218749.360
2	189418.314	218735.811	24	189619.661	218752.402
3	189427.823	218735.376	25	189631.769	218757.995
4	189435.820	218734.996	26	189641.693	218762.693
5	189443.824	218734.610	27	189648.779	218766.266
6	189458.678	218733.291	28	189658.342	218771.931
7	189474.978	218732.482	29	189665.167	218776.098
8	189484.497	218732.228	30	189674.343	218782.194
9	189492.490	218731.847	31	189680.900	218787.223
10	189500.837	218731.324	32	189690.385	218794.129
11	189510.314	218731.232	33	189694.494	218797.346
12	189514.372	218731.225	34	189708.092	218810.084
13	189524.515	218731.409	35	189712.075	218831.809
14	189528.485	218731.622	36	189724.792	218826.632
15	189536.545	218732.119	37	189733.245	218835.328
16	189543.957	218732.760	38	189741.569	218843.973
17	189552.339	218734.280	39	189749.716	218852.151
18	189561.410	218735.887	40	189758.689	218861.367
19	189573.676	218738.070	41	189764.819	218867.592
20	189584.284	218740.724	42	189776.011	218873.250
21	189594.014	218743.484	43	189776.011	218879.063
22	189064.837	218746.697			

Table 3.2.3. Observation data (B area)

No	X Coodinate (m)	Y Coodinate (m)	No	X Coodinate (m)	Y Coodinate (m)
1	226080.519	209755.544	29	226415.569	210075.213
2	226085.796	209762.450	30	226422.659	210077.838
3	226097.975	209775.856	31	226442.891	210082.978
4	226110.213	209789.299	32	226455.418	210086.428
5	226121.174	209801.486	33	226475.187	210089.427
6	226125.233	209807.173	34	226502.150	210091.094
7	226151.703	208836.875	35	226526.109	210091.764
8	226156.575	209842.526	36	226536.983	210092.164
9	226166.724	209852.718	37	226546.953	210092.466
10	226178.903	209868.155	38	226557.835	210092.951
11	226196.431	209887.709	39	226578.169	210093.475
12	226207.392	209899.896	40	226597.941	210093.230
13	226213.482	209907.615	41	226617.056	210092.858
14	226224.849	209920.208	42	226642.386	210092.855
15	226234.276	209931.235	43	226660.570	210093.606
16	226242.395	209939.766	44	226684.441	210092.305
17	226249.834	209949.525	45	226716.545	210092.120
18	226263.067	209964.759	46	226742.105	210092.120
19	226276.321	209979.309	47	226764.323	210092.118
20	226289.835	209993.695	48	226790.757	210091.383
21	226304.962	210008.802	49	226815.356	210091.384
22	226322.394	210023.209	50	226840.313	210091.388
23	226343.012	210039.093	51	226865.110	210090.652
24	226351.368	210044.541	52	226891.914	210091.200
25	226363.957	210051.245	53	226921.289	210090.465
26	226375.298	210057.455	54	226943.694	210090.652
27	226388.164	210064.039	55	226965.908	210090.287
28	226404.171	210070.900			

3.2.3 Data Calculation Method

In the data observed by point, the centerline path was calculated by means of indoor GPS post-management process, and the details are as follows.

1) Straight Line Path

To acquire a straight-line equation, the regression line like Figure 3.2.1 was used, and the IP coordinates were found using these two regression lines.

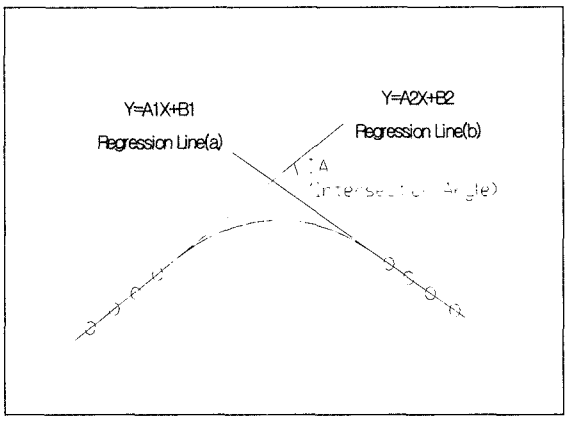

Fig. 3.2.1. Observation Point within Straight-line Section and Regression Line.

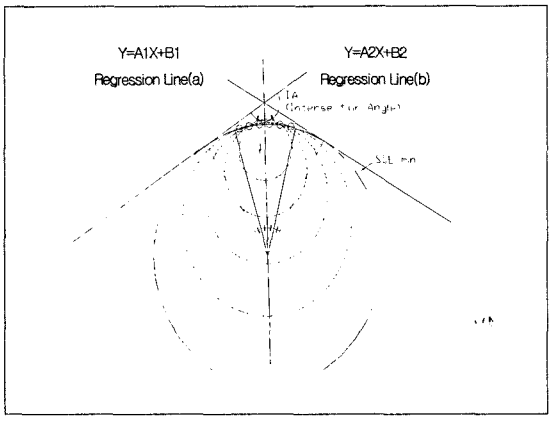

Fig. 3.2.2. R and the Center Point of Circular Curve.

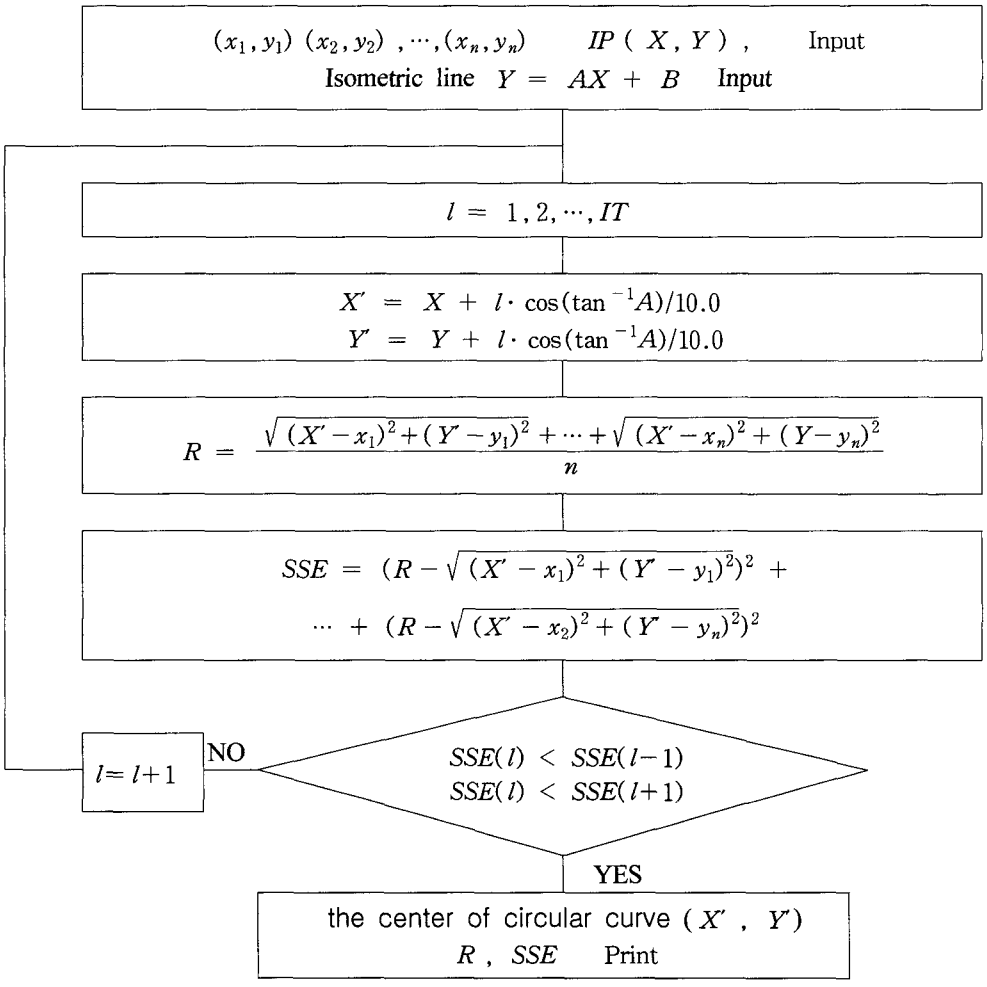

Fig. 3.2.3. R-Analysis Flow Chart.

2) Circular Curve Path

The minimum length of prescribed horizontal curve is set twice as long as the minimum transition section length. That is, the minimum horizontal length can be satisfied only with the transition curve, but in this case, it cannot be regarded as smooth handling, because the driver must hurriedly turn the steering wheel although the length condition to give a satisfactory curve was satisfied. Besides, as it is viewed as bent if sufficient attention is not paid to the establishment of super elevation, the curve does not give a smooth feeling to the driver. Therefore, it is desirable to insert a circular curve with some extents of length between these two transition curves. The analysis flow chart for finding value R in the circular curve section is shown in Figure 3.2.3.[4),6)]

As the center of circular curve is on the isometric line, the value R with the smallest SSE (Sum of Squares Error) and the center coordinates of circular curve was found by moving the center point of the circular curve by 10cm with IP coordinates as a starting point.

The program [1,2] was set to input the coordinates within the circular curve section, the isometric line of the two transition lines, and the IP coordinates in the following figure. In this study, R and the center point of circular curve was calculated by measuring the road center point within the circular curve section through a field investigation.

3) Clothoid Curve

In this study, A-parameter was found using the transition curve shift of Clothoid curve in Figure 3.2.4. The analysis flow chart is shown in Figure 3.2.5.

A shift is the extent to which the center of the circular curve was moved inward, when it is accessed directly to the circular curve from the straight line section without inserting a transition curve and when the transition curve is inserted into its interval. In other word, it means that the difference between the shortest distance between the straight line and the center point of transition line, and R.[7)]

In this study, a shift was regarded as the difference between the shortest distance between the center point

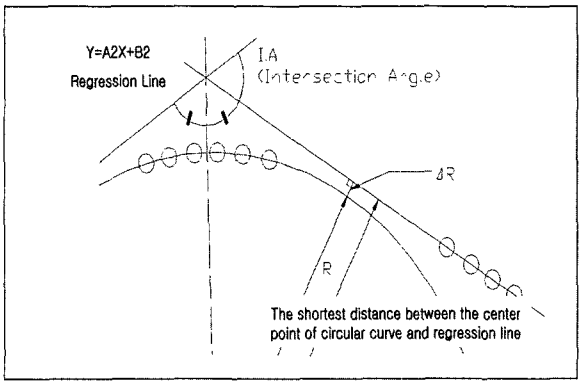

Fig. 3.2.4. Clothoid Curve Shift.

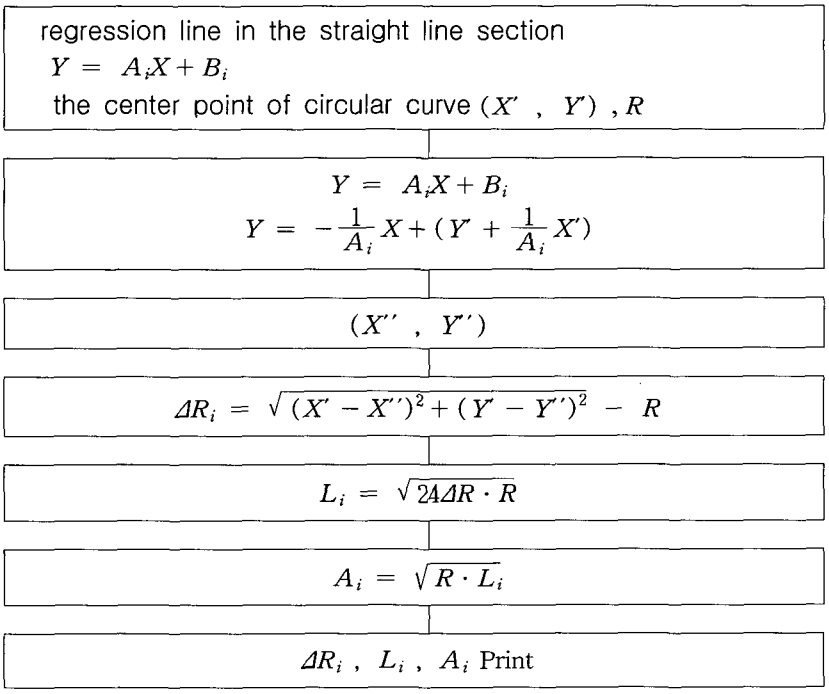

Fig. 3.2.5. A-Analysis Flow Chart.

of circular curve and regression line, and R. And a shift (ΔS), transition curve length and A were found using the value R found in the above, the center coordinates of circular curve and the regression line.

4. Analysis of Horizontal Alignment Path

4.1 Local Road Section Near Pusan

The measuring distance of road is about 80~90m and the chain distance is about 10m in the straight line section of Local Road near Pusan. The regression equation is as follows.

$$Y = 1.019519473X + 25398.65507 \quad \text{(a)}$$
$$Y = -0.054976497X + 229149.3683 \quad \text{(b)}$$

The center part of the circular curve section was found by dividing the distance between the two first points which miss the maximum residual in the straight line section in a ratio of 1 : 2 : 1.

The value R was obtained while moving the center point of the circular curve from IP-point and appreciated with the SSE of each point.

The SSE has the minimum value of 0.125m in the point that the distance from IP-point becomes 310.5m. The center point, the value R, and the residuals of distance of each point are shown in Figure 4.2.

4.2 National Road (NO. 35)

The measuring distance of road is about 260~380m and the chain distance is about 20m in National Road (NO. 35). The regression equation is as follows.

$$Y = -0.00806011X + 211919.7052 \quad \text{(a)}$$
$$Y = -0.00806011X + 211919.7052 \quad \text{(b)}$$

The center part of the circular curve section was found by dividing the distance between the two first points which miss the maximum residual in the straight line section in a ratio of 1 : 2 : 1.

The value R was obtained while moving the center point of the circular curve from IP-point and appreciated

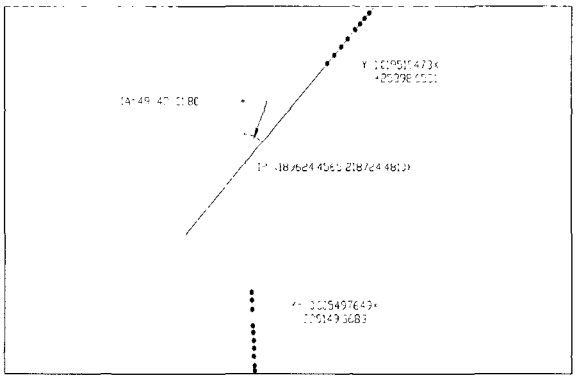

Fig. 4.1. IP and IA Local Road near Pusan.

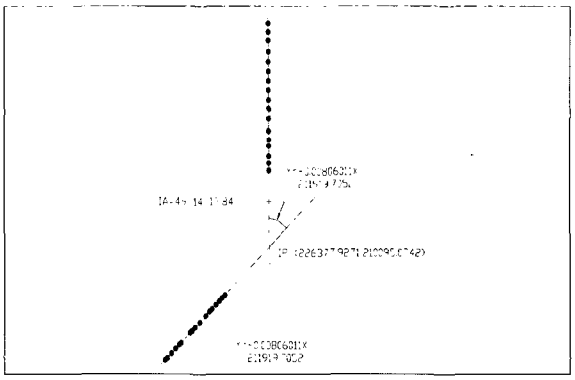

Fig. 4.3. IP and IA of National Road NO. 35.

circular curve center-point	circular radius of curve R
(226518.1, 209782.1)	310.583

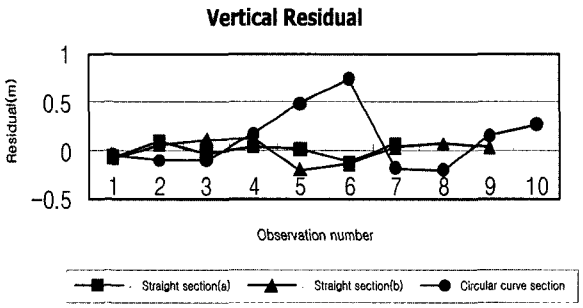

Fig. 4.2. Residuals of distance.

circular curve center-point	circular radius of curve R
(226518.1 , 209782.1)	310.583

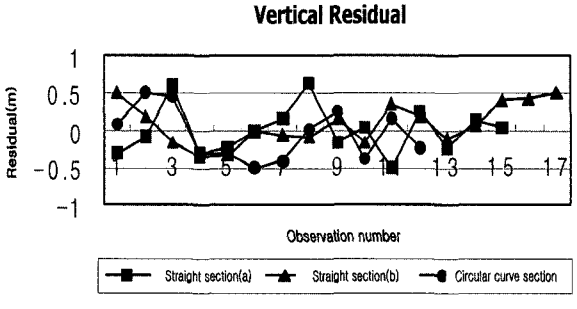

Fig. 4.4.1. Residuals of Distance.

with the SSE of each point.

The SSE has the minimum value of 0.958 in the point that the distance from IP-point becomes 343.0m. The center point, the value R, and the vertical residual of each point are shown in Figure 4.4.1.

4.3 Comparison and Analysis with the Execution Drawing

Table 4.3.1. Sampling Element in the Local Road near Pusan.

	Drawing and Specification Element	Sampling Element	Remarks
IP	X=189625.8 Y=218725.7	X=189624.457 Y=218724.481	X=1.343 Y=1.219
I	48° 15′ 05.72″	48° 42′ 01.80″	-26′ 56.08″
R	280m	282.719m	-2.719m
⊿R	0	0.1757m	-
L	0	34.7526m	-
A	0	99.0918	-

Table 4.3.2. Sampling Element in the National Road (NO. 35).

	Drawing and Specification Element	Sampling Element	Remarks
IP	X=226378.0 Y=210095.0	X=226377.927 Y=210095.074	X=0.073 Y=-0.074
I	49° 13′ 45.73″	49° 14′ 12.84″	-27.11″
R	300m	310.583m	-10.583m
⊿R	1.4459m	1.2519m	0.1940m
L	101.9521m	96.7158m	5.2363m
A	175	173.3170	1.6830

5. Conclusion

In this paper, the horizontal design elements were estimated by means of statistical inference, and its results are summarized as follows.

1. After estimating the horizontal alignment elements with the center line path of the road, in the first research area, the IP coordinate errors and the IA errors were analyzed as 1.2～1.3m and 26′ 56.08″ , respectively, while they were analyzed as 0.07m and 01′ 32.89″ , respectively in the second area. In the case of the length of the straight line section, the element estimation value using the observation value of the long straight line section (about 260～280m) was analyzed to have a smaller error range of IP coordinates and IA angle than the element estimation value that of the short one (about 80～90m).

2. The value R has the error of 3～11m and the value ⊿R, S (transition curve length) and A-parameter showed the errors of 0.2m, 5.2m and 1.7, respectively, in the National Road (NO. 35) near Pusan, ⊿R was within 0.2m. From this fact, it is able to be said that ⊿R is omissible distance.

3. The fact that the residuals of distance was 0.01～0.510m proves that the basic assumption is correct.

4. Furthermore, if the horizontal path of cars is gained (the research in the transverse path of cars should be preceded), the moving path that actual cars exercised upon running can be analyzed. Therefore, the effects that the geometrical structure of roads exerted upon traffic accidents can be analyzed comparatively and accurately.

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