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The Application of Excel in Highway Vertical Curve

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***Abstract*-When we are layouting field route, the calculation of designed elevation in vertical and horizontal section is big workload and very tedious. So using Excel which has powerful data processing function and convenient operation of the form to complete a large number of height calculation in vertical and horizontal section is very convenient and practical. The paper discussed about the elevation's calculation principle of middle and side stakes in vertical curve, and mainly studied the calculation method of superelevation transition section's elevation on the winding mountain road which was accomplished by Visual Basic for Application (VBA). Then we transform the result to the required format which can transfer to the total station, so the result could layout quickly and accurately at the scene. In short, using Excel to calculate vertical curve elevation is very simple and practical. It will not only greatly improve working efficiency, but also reduce the chance of errors.**

Keywords-vertical curve; elevation; superelevation; visual basic for application

I. INTRODUCTION

In the reforming period of society the urbanization is inevitable, and the highway is the hub of all cities, so it is very important. Vertical curve is a necessary line form in highway design and construction. Therefore studying a fast method for calculating elevation of middle and side stakes in vertical curve at different points has the very vital significance. In the previous days, we adopted the calculator to calculate the designed elevation point by point in highway vertical curve calculation, but the efficiency and fallibility of this method is very low. AutoCAD visual-lisp and Excel VBA programming language can both complete the calculation of vertical curve. With the two new methods we need not input point by point but calculate a series of points' elevation. So using Excel VBA to handle complicated elevation calculation of vertical curve is very simple and practical.

II. VERTICAL CURVE

In the design of road engineering, in order to adapt to the needs of terrain changes and drainage, it's necessary to set longitudinal slope. But when two adjacent longitudinal slopes intersect, there will be a grade-changing point. Vehicles will bump down when passing through this point, and driving smooth is damaged [1]. Besides slope-changing point will also obstruct the driver's view and affect driving safety. In order to reduce this effect, it is necessary to set a curve instead of the original polyline at the slope-changing point, the curve is called a vertical curve.

The purpose of vertical curve calculation is to determine subgrade design elevation at specified stake numbers design longitudinal grade, as shown in figure 1.

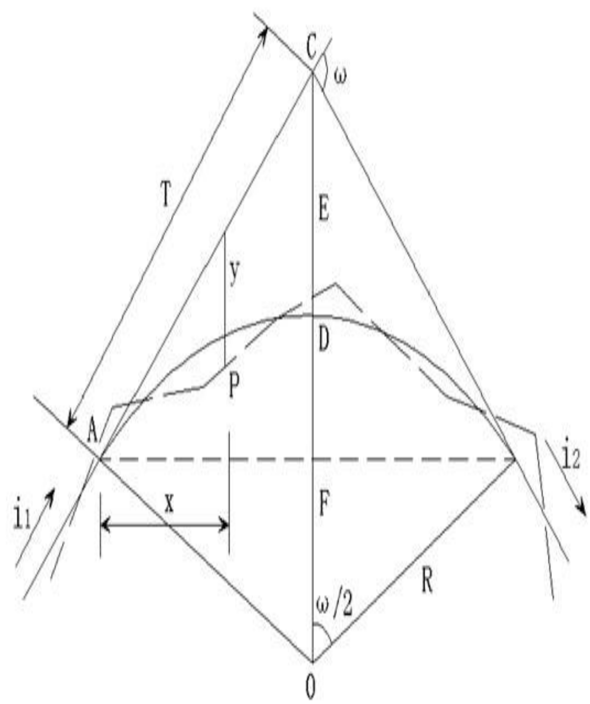

Figure 1. Vertical curve.

The vertical curve elevation calculation steps are as follows [2]:

(1) curve factors

$$\alpha = abs(i_1 - i_2)$$

$$T = R * \alpha / 2$$

$$L = R * \alpha$$

$$E = T^{\wedge 2} / R / 2$$

Type: i ——designed longitudinal gradient of vertical curve

R ——radius of vertical curve

α —— corner

T —— tangent length
L —— curve length
E —— apex distance
(2) the starting and end points' mileage

$$qd1c = bpd1c - T$$

$$zd1c = bpd1c + T$$

Type: $qd1c$ ——the starting points' mileage
$bpd1c$ ——the end points' mileage
$zd1c$ ——the grade-changing points' mileage
(3) any point's tangent elevation and correction value on the vertical curve

$$Tgc = bpdgc \pm (T - x) * i$$

$$y = x\hat{}2 / 2 / R$$

$$Cgc = Tgc - y$$

Type: Tgc ——tangent elevation
$bpdgc$ ——grade-changing point elevation
Cgc ——curve elevation
y ——correction value

III. SUPERELEVATION

A. The Definition

The train can produce centrifugal force when running on the curve, and the size of centrifugal force depends on the train weight, driving speed and the radius of circular curve [3]. Because of the influence of centrifugal force, the curve outer rail load increases suddenly and the inner rail load pressure decreases accordingly. When it exceeds a certain limited value, the train has the danger of derailing and overturning. In order to offset the adverse impact of the centrifugal force, railway adopts elevation of outer rail method on the curve part [4], which raises the outer rail to a certain value, makes the vehicle inclined to the inside of the curve, balances the action of centrifugal force, and ensures the safe operation of the train. Moreover due to the structure of the vehicle structure, it is necessary to widen the inner rail.

Generally there are three ways of decreasing transverse force: increasing the curve radius, slowing down driving speed and increasing the transverse slope tilted to the inside [5]. But increasing curve radius is difficult and slowing down driving speed is not recommended in the design, so the effect of setting superelevation is the best and the cost is lowest. Superelevation cross-section diagram is shown in figure 2.

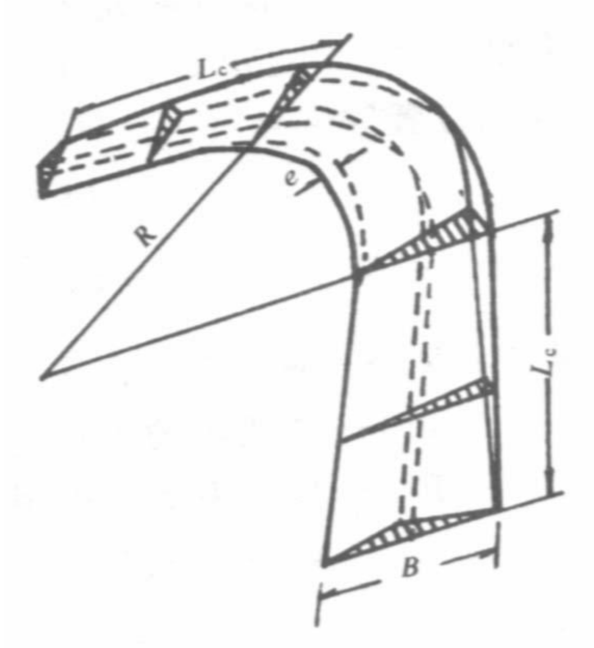

Figure 2. Cross-section diagram of superelevation

B. Forming process

The process of generating superelevation is divided into four stages [6]:

1) Preparation Stage: within the range of 1 ~ 2 m before getting into superelevation transition curve zone, the road should be lift its shoulder's transverse gradients up to the same as the road surface, namely the subgrade top turns into simple bidirectional transverse gradients.

2) Double way gradient stage: in superelevation transition curve zone, keeping the inside road motionless, and the outside road rotates about midline up to inside road's transverse gradients, the length of the process is called the length of double way gradient length. According to the requirement of superelevation runoff, a change in distance to transition curve zone's starting point is directly proportional to a change in crown slope.

3) Rotating stage: when the outside pavement becomes the one-way introversive transverse slope same as that of inside road, keeping the inside road motionless, then the road rotates about inner edge up to superelevation transverse slope and ends up at terminal point of transition curve zone.

4) Full superelevation stage

C. Calculation methods

Superelevation value is elevation difference between calculation points of subgrade design elevation, midline and road edge and shoulder edge's elevation after setting superelevation. The number of the method in superelevation transition is very big, but this paper mainly introduces rotating around the edges in the line of superelevation transition way [7]. If there is no special note, all is the way of transition.

(1) normal section

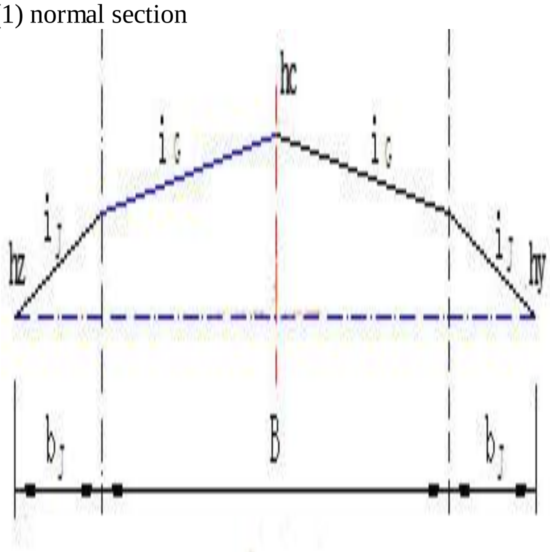

Figure 3. Diagram of normal section

$$hc = b_j * i_j + B * i_g / 2$$

$$hy = b_j * i_j$$

$$hz = 0$$

Type: hc, hz, hy ——the superelevation of the road midline, pavement and shoulder respectively

b_j, B ——the width of shoulder and pavement respectively

i_j ——the transverse gradient of shoulder

i_g ——the transverse gradient of crown

(2) initial section

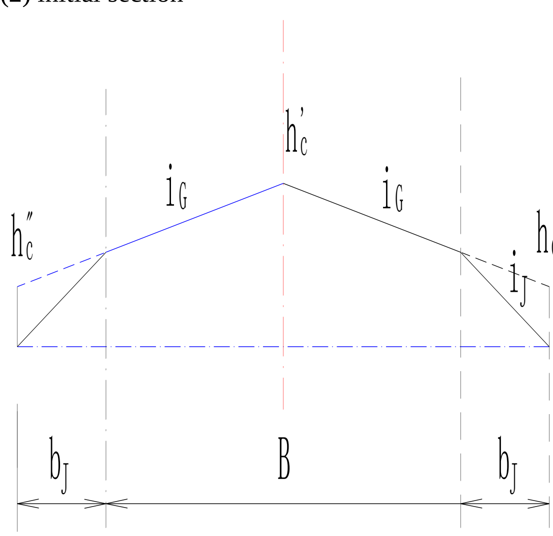

Figure 4. Diagram of initial section

$$h_c' = b_j * i_j + B * i_g / 2$$

$$h_c = h_c'' = b_j * (i_j - i_g)$$

Type: h', h'', h ——the superelevation of the road midline, inside edge line and outside edge line respectively

(3) double way gradient section

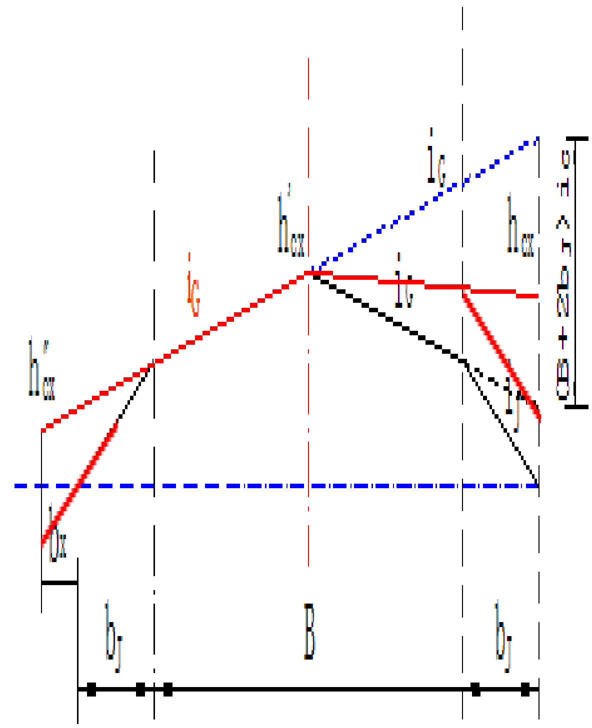

Figure5. Diagram of double way gradient section.

$$x_0 = i_g * lc / i_b$$

$$h_{cx} = b_j * (i_j - i_g) + \frac{x}{x_0} * (B + 2 * b_j) * i_g$$

$$h_{cx}' = b_j * i_j + B * i_g / 2$$

$$h_{cx}'' = b_j * i_j - (b_j + b_x) * i_g$$

Type: $h_{cx}', h_{cx}'', h_{cx}$ ——the superelevation of the road midline, inside edge line and outside edge line respectively

x_0 ——the length of double way gradient section

i_b ——the transverse gradient of superelevation

b_x ——the widening value at any point

(4) rotating section

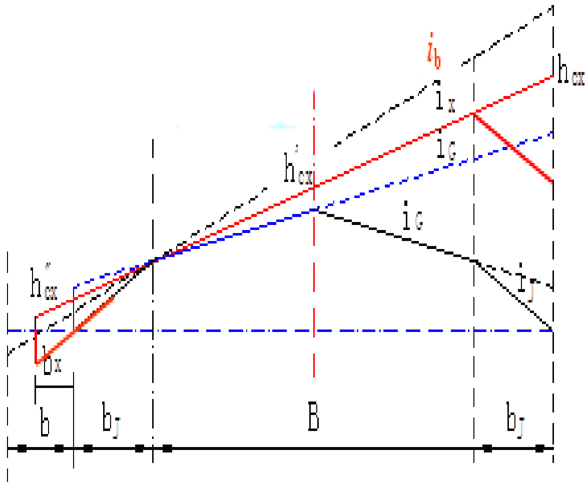

Figure 6. Diagram of rotating section.

$$i_x = x / lc * i_b$$

$$h_{cx} = b_j * i_j + (B + b_j) * i_x$$

$$h_{cx}' = b_j * i_j + B * i_x / 2$$

$$h_{cx}'' = b_j * i_j - (b_j + b_x) * i_x$$

Type: lc ——the length of the transition curve

i_x ——the transverse gradient of rotating section

(5) full superelevation section

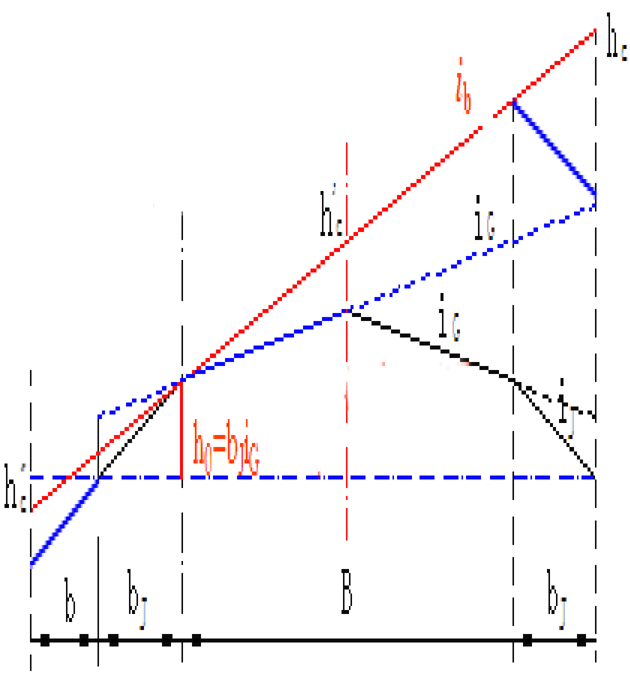

Figure7. Diagram of full superelevation section.

$$h_{cx} = b_j * i_j + (B + b_j) * i_b$$

$$h_{cx}' = b_j * i_j + B * i_b / 2$$

$$h_{cx}'' = b_j * i_j - (b_j + b) * i_b$$

Type: b ——the widening value

IV. ARITHMETIC EXAMPLE

A. Data Sources and Analysis

In this example the initial data is shown in table 1 below, suppose that midpoint of vertical curve and midpoint of plane curve is overlapped, so accordingly mileage of grade-changing point is the same as that of midpoint of plane curve, which equals to two different slopes meet in grade-changing point on the profile of winding mountain road.

TABLE I. INITIAL DATA

Data Types	Factors		Value
	radius		5000m
data of vertical curve	***the longitudinal gradient***	i_1	1.114%
		i_2	-0.154%
	the transverse gradient	i_j	3.000%
		i_g	2.000%
		i_b	6.000%
	b		0.8m
	b_j		0.75m
	B		8m
The backsight point	***ZDB1***	***X***	3160.56m
		Y	1002.34m
The front view point	***ZDF1***	***X***	3132.33m
		Y	1400.28m
The point of intersection	***JD1***	***X***	3260.88m
		Y	1240.04m
		JDLC	K1+324.66
data of circular curve	***radius***		250m
	lc		70m
	The height of straight-spiral point		48.6m

B. Building Model

According to the data determines the main points mileage on the plane curve which include coordinates and mileage data of forward-looking intersection point, intersection point and back intersection point, radius data of circular curve and length data of transition curve. Then using the straight-spiral point elevation calculates grade-changing point elevation [8]. Finally superelevation are computed by the road shoulder width and transverse slope [9]. The calculation results are shown in table 2 below.

TABLE II. THE RESULT TABLE

stake numbers	designed elevation	b_x	i_x	h_{cx}'	h_{cx}''	h_{cx}	H_{cx}'	H_{cx}''	H_{cx}
K1+140.110	48.6000	0.0000	0.000%	0.1	0.01	0.01	48.7000	48.6100	48.6100
K1+150.110	48.7114	0.1143	0.857%	0.1	0.01	0.09	48.8114	48.7214	48.8014
K1+160.110	48.8228	0.2286	1.714%	0.1	0	0.17	48.9228	48.8228	48.9928
K1+170.110	48.9342	0.3429	2.571%	0.13	-0.01	0.25	49.0642	48.9242	49.1842
K1+180.110	49.0456	0.4571	3.429%	0.16	-0.02	0.32	49.2056	49.0256	49.3656
K1+190.110	49.1570	0.5714	4.286%	0.19	-0.03	0.4	49.3470	49.1270	49.5570
K1+200.110	49.2684	0.6857	5.143%	0.23	-0.05	0.47	49.4984	49.2184	49.7384
K1+210.110	49.3798	0.8000	6.000%	0.26	-0.07	0.55	49.6398	49.3098	49.9289
K1+248.977	49.8128	0.8000	6.000%	0.26	-0.07	0.55	50.0728	49.7428	50.3628
K1+268.977	50.0356	0.8000	6.000%	0.26	-0.07	0.55	50.2956	49.9656	50.5856
K1+288.977	50.2584	0.8000	6.000%	0.26	-0.07	0.55	50.5184	50.1884	50.8084
K1+308.977	50.4812	0.8000	6.000%	0.26	-0.07	0.55	50.7412	50.4112	51.0312
K1+328.977	50.4575	0.8000	6.000%	0.26	-0.07	0.55	50.7175	50.3875	51.0075
K1+348.977	50.4267	0.8000	6.000%	0.26	-0.07	0.55	50.6867	50.3567	50.9767
K1+368.977	50.3959	0.8000	6.000%	0.26	-0.07	0.55	50.6559	50.3259	50.9459
K1+388.977	50.3651	0.8000	6.000%	0.26	-0.07	0.55	50.6251	50.2951	50.9151
K1+408.977	50.3343	0.8000	6.000%	0.26	-0.07	0.55	50.5943	50.2643	50.8843
K1+408.980	50.3343	0.8000	6.000%	0.26	-0.07	0.55	50.5943	50.2643	50.8843
K1+418.980	50.3422	0.6857	5.143%	0.23	-0.05	0.47	50.5722	50.2922	50.8122
K1+428.980	50.3268	0.5714	4.286%	0.19	-0.03	0.4	50.5168	50.2968	50.7268
K1+438.980	50.3114	0.4571	3.429%	0.16	-0.02	0.32	50.4714	50.2914	50.6314
K1+448.980	50.2960	0.3429	2.571%	0.13	-0.01	0.25	50.4260	50.2860	50.5460
K1+458.980	50.2806	0.2286	1.714%	0.1	0	0.17	50.3806	50.2806	50.4506
K1+468.980	50.2652	0.1143	0.857%	0.1	0.01	0.09	50.3652	50.2752	50.3552
K1+478.980	50.2498	0.0000	0.000%	0.1	0.01	0.01	50.3498	50.2598	50.2598

V. CONCLUSION

In the design of highway profile, it is necessary to calculate a lot of the designed elevation of middle and side stakes in vertical curve, especially the design elevation at any point. Calculation workload with manual is great and error-prone, so we can use Excel programming to solve this problem. Using Excel powerful editing and computing functions, we can input mileage and elevation of the change slope points and radius into the designed program, and calculate the designed elevation of middle and side stakes which can save time and money, and improve work efficiency.

In a word, the paper introduced the principle method of calculating vertical curve design elevation superelevation, using the Excel VBA [10] to solve a lot of tedious calculation problem. With examples we demonstrated that calculating vertical curve and elevation by Excel is very simple and practical.

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