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Highway Middle Pile Coordinate Automatic Calculation based on Combine of Excel and Excel VBA Program

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Abstract. In the highway design and construction, it is common to calculate the middle pile point coordinates. Application the data calculation, data processing function and function library of Excel software establish worksheet calculation model of route transverse. Then using Excel VBA program achieves automatic calculation of road middle pile point coordinates. Results show, this fast and accurate calculation method has strong practicality and generality and can be used as a reference for the highway construction personnel.

Introduction

In the construction of highway, Global Positioning System (GPS), Total Station have been widely used which are essential especially during the construction of high-grade highway. Regardless of what the method might be, the middle pile points coordinates are need when put in the line. Although various kinds of design software can provide these data, but the use of these software are limited to the design institutes. Most of middle state points coordinates can only be manual calculated for the engineering and technical personnel not working in the design institute. The number of middle pile points are hundreds, thousands or more in a route, so the calculation is a great work and long period by hand. Besides the huge workload and complex calculation procedures, it is easy to appear mistake and the calculation precision is difficult to guarantee. It can avoid the defects of manual calculation if the work accomplished by the software Excel and VBA. Excel software itself has a powerful calculation function but cannot be complex logic judgment and duplicated data processing. If combining Excel software and VBA program, the fast and high precision automatic calculation can be realized for the highway middle pile points coordinates.

Coordinate Azimuth *A*, Length *S*, Rotating α Calculation of Traverse

It is need base data during highway middle pile points coordinates calculation, such as route intersection points coordinates, intersection points distance, computation azimuth, corners, horizontal curve elements and so on. Established route intersection coordinates in the route design are known data. Route middle pile points range and coordinates are calculated by Excel and VBA program, and most of the rest basic data are calculated by Excel software to complete.

As shown in Figure1, coordinate X_{JD} and Y_{JD} of Intersection *JD* are known and the coordinate azimuth *A*, distance *S* between the intersection of routed transverse can be calculated by the following formula.

Azimuth: $$A_{i-1,i} = tg^{-1}\frac{Y_i - Y_{i-1}}{X_i - X_{i-1}} \quad (1)$$

Intersection Distance: $$S = \sqrt{(X_i - X_{i-1})^2 + (Y_i - Y_{i-1})^2} \quad (2)$$

Where, X_{i-1} and Y_{i-1} is coordinate of point *i*-1； X_i and Y_i is coordinate of point *i*.

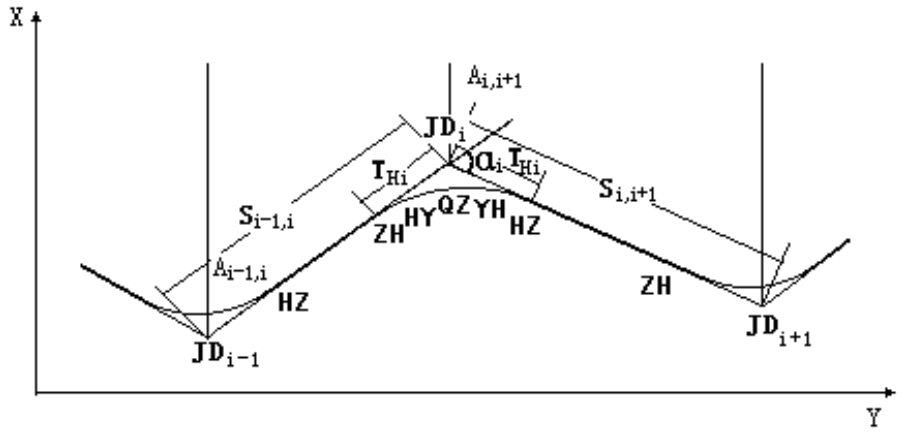

Fig.1. Middle pile coordinate calculation

Middle Pile Coordinate Calculation

Middle Pile Coordinate between HZ Point (Including Route Starting Point) and HZ Point. As shown in Figure 1, for straight line, the coordinates of pile points can be calculated as follows.

$$\begin{aligned} X_i &= X_{HZi-1} - D_i \cos A_{i-1,i} \\ Y_i &= Y_{HZi-1} - D_i \sin A_{i-1,i} \end{aligned} \tag{3}$$

Where, $A_{i-1,I}$ is coordinate azimuth of route transverse JD_{i-1}—JD_i, D_i is distance between pile point and point HZ_{i-1} which is difference between pile point mileage and point HZ_{i-1} mileage, X_{HZi-1} and Y_{HZi-1} are coordinates of point HZ_{i-1} which can be calculated as follows.

$$\begin{aligned} X_{HZi-1} &= X_{JDi-1} - T_{Hi-1} \cos A_{i-1,i} \\ Y_{HZi-1} &= Y_{JDi-1} - T_{Hi-1} \sin A_{i-1,i} \end{aligned} \tag{4}$$

Where, X_{JDi-1} and Y_{JDi-1} is coordinate of intersection point JD_{i-1}, T_{Hi-1} is tangent length, ZH is point of end line. Beside the formula (3) can follow, it can also be calculated as follows.

$$\begin{aligned} X_{HZi} &= X_{JDi-1} + (S_{i-1,i} - T_{Hi}) \cos A_{i-1,i} \\ Y_{HZi} &= Y_{JDi-1} + (S_{i-1,i} - T_{Hi} \sin A_{i-1,i} \end{aligned} \tag{5}$$

Where, $S_{i-1,i}$ is side length of tangent JD_{i-1}—JD_i.

Pile Coordinate from Point ZH to Point YH. This segment including the first easement curve and circular curve, the tangent offset coordinate x and y of pile point can first be calculated.

***Arbitrary Point on the Easement Curve*.** The curve equation is as follows.

$$\begin{cases} x = l - \dfrac{l^5}{40R^2 l_s^2} \\ y = \dfrac{l^3}{6Rl_s} \end{cases} \tag{6}$$

Where, l is curve length from pile point to easement curve starting point ZH, R is circular curve radius, l_s is length of easement curve.

***Pile Point on the Curve*.** The coordinates equation of pile point on the curve is as follows.

$$\begin{cases} x = R\sin\phi + q \\ y = R(1-\cos\phi) + p \end{cases} \tag{7}$$

Where, $\varphi = \beta_0 + \dfrac{l}{R}\dfrac{180°}{\pi}$, l is curve length form pile point to HY which is only the length of curve part. It can convert to measure coordinate X and Y through the coordinate transformation. The coordinate transformation as follows.

$$\begin{bmatrix} X_i \\ Y_i \end{bmatrix} = \begin{bmatrix} X_{ZHi} \\ Y_{ZHi} \end{bmatrix} + \begin{bmatrix} \cos A_{i-1,i} & -\sin A_{i-1,i} \\ \sin A_{i-1,i} & +\cos A_{i-1,i} \end{bmatrix} \begin{bmatrix} x_i \\ y_i \end{bmatrix} \tag{8}$$

Using formula (8) to calculate, it should substitute $y_i = -y_i$, when the curve turn left.

Pile Point Coordinate from Point YH to Point HZ. This segment is the second easement curve, the tangent offset coordinate can also be calculated as formula (7) and convert to measure coordinate as follows.

$$\begin{bmatrix} X_i \\ Y_i \end{bmatrix} = \begin{bmatrix} X_{ZHi} \\ Y_{ZHi} \end{bmatrix} - \begin{bmatrix} \cos A_{i,i+1} + \sin A_{i,i+1} \\ \sin A_{i,i+1} - \cos A_{i,i+1} \end{bmatrix} \begin{bmatrix} x_i \\ y_i \end{bmatrix} \tag{9}$$

It should substitute $y_i = -y_i$, when the curve turn right.

Build Foundation Data Calculation Model

Coordinate Azimuth *A*, Length *S*, Rotating *α* Calculating Model. Establish the coordinate azimuth *A*, length *S*, rotating αin worksheet sheet1 including coordinate increment, coordinate incremental correction, corrected increment, coordinate azimuth, rotating and so on. At the same time increase the auxiliary calculation for checking. It is relatively simple calculation that just put the formula into the corresponding cell, estimate the coordinate azimuth according the quadrant location when coordinate azimuth calculation and judge routes turning according coordinate azimuth.

It should make full use of fill handle to automatic fill data in the calculation processing and the calculation results are shown in Figure 2.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Intersection	Intersection coordinates		Intersection distance (m)	Coordinate increment (m)		Incremental correction (m)		Corrected increment (m)		Coordinate azimuth		Turning	Rotation Angle	
2		N (X)	E (Y)		Δx	Δy	Δx	Δy	Δx	Δy	Radians	° ′ ″		Radians	° ′ ″
3	Origin	3000.00	3000.00								1.310	75° 04′ 06.89″			
4	JD1	3080.00	3300.00	310.483	80.00	300.00	0.00	0.00	80.00	300.00	1.768	101° 18′ 35.75″	Right-Turn	0.458	26° 14′ 28.85″
5	JD2	3020.00	3600.00	305.941	-60.00	300.00	0.00	0.00	-60.00	300.00	1.197	68° 36′ 00.68″	left-turn	0.571	32° 42′ 35.07″
6	JD3	3165.00	3970.00	397.398	145.00	370.00	0.00	0.00	145.00	370.00	2.182	124° 59′ 31.27″	Right-Turn	0.984	56° 23′ 30.58″
7	JD4	3025.00	4170.00	244.131	-140.00	200.00	0.00	0.00	-140.00	200.00	1.551	88° 51′ 15.25″	left-turn	0.631	36° 08′ 16.01″
8	JD5	3030.00	4420.00	250.050	5.00	250.00	0.00	0.00	5.00	250.00	2.596	148° 42′ 47.77″	Right-Turn	1.045	59° 51′ 32.52″
9	JD6	2770.00	4578.00	304.243	-260.00	158.00	0.00	0.00	-260.00	158.00	2.361	135° 15′ 41.84″	left-turn	0.235	13° 27′ 05.93″
10	JD7	2440.00	4905.00	464.574	-330.00	327.00	0.00	0.00	-330.00	327.00	1.510	86° 30′ 19.29″	left-turn	0.851	48° 45′ 22.54″
11	JD8	2480.00	5560.00	656.220	40.00	655.00	0.00	0.00	40.00	655.00	1.993	114° 11′ 14.47″	Right-Turn	0.483	27° 40′ 55.17″
12	JD9	2215.00	6150.00	646.780	-265.00	590.00	0.00	0.00	-265.00	590.00	1.209	69° 15′ 14.11″	left-turn	0.784	44° 56′ 00.36″
13	JD10	2340.00	6480.00	352.881	125.00	330.00	0.00	0.00	125.00	330.00	2.119	121° 25′ 46.43″	Right-Turn	0.911	52° 10′ 32.32″
14	JD11	2120.00	6840.00	421.900	-220.00	360.00	0.00	0.00	-220.00	360.00	1.581	90° 33′ 42.13″	left-turn	0.539	30° 52′ 04.29″
15	JD12	2115.00	7350.00	510.025	-5.00	510.00	0.00	0.00	-5.00	510.00	1.943	111° 21′ 03.52″	Right-Turn	0.363	20° 47′ 21.38″
16	End Point	1900.00	7900.00	590.529	-215.00	550.00	0.00	0.00	-215.00	550.00					
17															
18	Σ			5455	-1100	4900	0	0	-1100	4900					
19		Σβ=	2161	$f_{\beta测}$=	0.000	Σ Δx=	-1100	Σ Δy=	4900						
20	Auxiliary calculation	f_β=	0.000	allow	0.000	f_x=	0.000	f_y=	0.000						
21		$f_{\beta allow}$=	0.038			f_D=	0.000								
22		Σ D=	5455			K=	0.000	allow	K_{allow}	0.001					

Sheet1 / Sheet2 / Sheet3 / Sheet4

Fig.2. The coordinate azimuth A and length S and rotating α calculating model

Horizontal Curve Elements and Main Point Mileage Calculation Model. Establish the horizontal curve elements and main point mileage calculation model in worksheet sheet2 as show in Figure 3. Circular curve radius and easement curve length are known data or can adjust according need. The rest data only need to fill in the corresponding cell based on calculation formula and then make full use of the fill handle to populate the data automatically.

Excel VBA Program Design

Excel software itself proved to be more powerful calculation function and can complete middle pile coordinate calculation of a single horizontal curve. But there are large numbers of horizontal curve on a route, so Excel software itself cannot be logical judgement and duplicate data processing. It must use Excel VBA program to solve that problem and achieving the automatic computing of pile point mileage and pile point coordinates.

Pile Point Mileage Calculation Program Design. It must calculate the pile point mileage

before the pile point coordinate calculation, meanwhile ensure the pile point mileage correspondence with pile coordinates. Due to the different degree of route technology level and complex terrain, the adopted pile spacing is not the same. As is well-known, modern roads are generally composed of three kinds of linear, straight line, circular curve and easement curve. Usually straight line space slightly large, pile points of curve segment will be encrypted. In order increase the versatility of program, read pile distance from worksheet Sheet2 and the next sections will describe each of program.

Intersection	Radius (m)	Intersection mileage (m)	Length of easement curve (m)	Straight segment length (m)	Easement curve tangent angle: Radians	Easement curve tangent angle: ° ′ ″	Curvilinear element: Tangent increment (m)	Tnside movement value (m)	Total length of tangent (m)	Circular curve length (m)	Total length of curve (m)	External distance (m)	Super distance (m)	Mileage of main point of curve: Straight line and clothoid mileage (m)	Easement and circle curve mileage (m)	Curve center mileage (m)	Circle curve and clothoid mileage (m)	Clothoid and straight line mileage (m)	Intersection mileage calibration
Origin		0.00																	
JD1	260.00	310.48	70	214.72	0.13	7° 42′ 46.41″	34.98	0.785	95.76	49.08	189.08	7.78	2.45	214.72	284.72	309.26	333.80	403.80	310.48
JD2	300.00	613.97	70	86.95	0.12	6° 41′ 04.22″	34.98	0.681	123.22	101.27	241.27	13.36	5.18	490.75	560.75	611.39	662.02	732.02	613.97
JD3	166.35	1006.20	100	133.80	0.30	17° 13′ 16.49″	49.85	2.505	140.37	63.73	263.73	25.24	17.02	865.82	965.82	997.69	1029.55	1129.55	1006.20
JD4	162.70	1233.31	100	0.00	0.31	17° 36′ 30.02″	49.84	2.561	103.76	2.62	202.62	11.13	4.90	1129.55	1229.55	1230.86	1232.17	1332.17	1233.31
JD5	165.00	1478.46	100	0.00	0.30	17° 21′ 44.48″	49.85	2.525	146.29	72.38	272.38	28.30	20.20	1332.16	1432.16	1468.36	1504.55	1604.55	1478.46
JD6	600.00	1762.50	70	52.16	0.06	3° 20′ 32.11″	35.00	0.340	105.79	70.87	210.87	4.50	0.72	1656.70	1726.70	1762.14	1797.57	1867.57	1762.50
JD7	200.00	2226.35	90	222.46	0.23	12° 53′ 29.58″	44.92	1.688	136.32	80.19	260.19	21.43	12.45	2090.03	2180.03	2220.12	2260.22	2350.22	2226.35
JD8	800.00	2870.12	70	287.73	0.04	2° 30′ 24.08″	35.00	0.255	232.17	316.51	456.51	24.19	7.82	2637.95	2707.95	2866.21	3024.46	3094.46	2870.12
JD9	300.00	3509.08	70	255.29	0.12	6° 41′ 04.22″	34.98	0.681	159.33	165.27	305.27	25.38	13.38	3349.75	3419.75	3502.39	3585.02	3655.02	3509.08
JD10	260.00	3848.58	70	30.89	0.13	7° 42′ 46.41″	34.98	0.785	162.67	166.77	306.77	30.37	18.57	3685.91	3755.91	3839.29	3922.68	3992.68	3848.58
JD11	600.00	4251.91	70	58.49	0.06	3° 20′ 32.11″	35.00	0.340	200.74	253.25	393.25	22.80	8.23	4051.17	4121.17	4247.79	4374.42	4444.42	4251.91
JD12	500.00	4753.70	70	182.50	0.07	4° 00′ 38.53″	34.99	0.408	126.79	111.42	251.42	8.76	2.16	4626.91	4696.91	4752.63	4808.34	4878.34	4753.70
End point		5342.08																	
Intersection number	12																		
Straight segment pile spacing	20																		
Curve segment pile spacing	10																		

Sheet1 Sheet2 Sheet3 Sheet4

Fig.3. The horizontal curve elements and main point mileage calculation model

Read Basic Data. First define each required variable, then read the required data from Sheet2 which including them number of intersection point, starting point mileage, ending point mileage, straight-easement point mileage, easement-circular point mileage, middle curve point mileage, circular-easement point mileage, easement-straight point mileage. Procedure is as follows.

```
Dim j, jds, m ,zj1,zj2 As Integer
Dim qdlc, zdlc, lc As Double
Dim zh(12), hy(12), qz(12), yh(12), hz(12)
As Double
With Sheets("Sheet2")
zj1=.Cells(17, 2)
zj2=.Cells(17, 2)
qdlc = .Cells(3, 3)
zdlc = .Cells(16, 3)
jds = .Cells(17, 2)
End With
With Sheets("Sheet2")
j = 1
Do While j <= jds
zh(j) = .Cells(j + 3, 15)
hy(j) = .Cells(j + 3, 16)
qz(j) = .Cells(j + 3, 17)
yh(j) = .Cells(j + 3, 18)
hz(j) = .Cells(j + 3, 19)
j = j + 1
Loop
End With
```

Pile Point Mileage Calculation Program Design. The constitute characteristics of route transverse are as follows, the reversed cyclic of Segment of point *HZ* (including starting point) to point *PZ* point, Segment of point *HY* to point *YH* point, Segment of point *YH* to point *HZ* point constitute the whole road transverse. Segment of Point HZ (including route starting point) to point *HZ* is straight line and generally set the pile points by whole number method. Segment of point *ZH* to point *HY* and point *YH* to point *HZ* are easement curve and set the pile points by whole number method or whole spacing method. It is generally adopted whole number method to set pile points for the segment of point *HY* to points *YH*. In addition, the main pile point on the curve also is the control point. Program design should fully consider the characteristics of each segment. Due to the limitation, this paper give part of program source code as follows.

Middle pile points mileage calculate program between Point *HZ* (including starting point) and point *HZ* as follow.

```
Do While lc < zh(j)
If lc + zj1 < zh(j) Then
```

```
If Int(lc / zj1) = lc / zj1 Then
lc = lc +zj1
Else
lc = (Int(lc / zj1) + 1) * zj1
End If
Cells(m, 3) = lc
m = m + 1
```

Middle pile points mileage calculate program between Point ZH and point YH as follow.

```
Do While lc <= hy(j)
x0 = (lc - lc0) - (lc - lc0) ^ 5 / (40 * r(j) ^ 2 * ls(j) ^ 2)
y0 = (lc - lc0) ^ 3 / (6 * r(j) * ls(j))
If zx(j) = "left-turn" Then
y0 = -y0
End If
zbx = qdzbx + x0 * Cos(fwj(j - 1)) - y0 * Sin(fwj(j - 1))
zby = qdzby + x0 * Sin(fwj(j - 1)) + y0 * Cos(fwj(j - 1))
Cells(m, 4) = zbx
Cells(m, 5) = zby
m = m + 1
lc = .Cells(m, 3)
Loop
```

Pile Point Coordinate Calculation Program Design. The pile point coordinate calculation is similar to the pile point mileage calculation, and the base data need read from worksheet Sheet1 and Sheet2. Based on the calculation formula, beside the straight line before ending pint it can be divided into segment of point *HZ* (including starting point) to point *HZ*, segment of point *ZH* to point *YH*, segment of point *YH* to point *HZ*.

Read basic data as follows.

```
Dim j, jds, m As Integer
Dim lc, qdzbx, qdzby, zbx, zby, lc0, x0, y0 As Double
Dim zh(15), hy(15), qz(15), yh(15), hz(15), fwj(15), qxzl(15) As Double
Dim r(15), ls(15), jdzbx(15), jdzby(15), qxj(15), qxc(15), nyz(15) As Double
Dim zx(15) As Variant
With Sheets("Sheet2")
jds = .Cells(17, 2)
j = 1
Do While j <= jds
zh(j) = .Cells(j + 3, 15)
hy(j) = .Cells(j + 3, 16)
qz(j) = .Cells(j + 3, 17)
yh(j) = .Cells(j + 3, 18)
hz(j) = .Cells(j + 3, 19)
r(j) = .Cells(j + 3, 2)
ls(j) = .Cells(j + 3, 4)
qxj(j) = .Cells(j + 3, 6)
qxzl(j) = .Cells(j + 3, 8)
nyz(j) = .Cells(j + 3, 9)
qxc(j) = .Cells(j + 3, 10)
j = j + 1
Loop
End With
With Sheets("Sheet1")
j = 1
Do While j <= jds
zx(j) = .Cells(j + 3, 13)
j = j + 1
Loop
j = 0
Do While j <= jds
jdzbx(j) = .Cells(j + 3, 2)
jdzby(j) = .Cells(j + 3, 3)
fwj(j) = .Cells(j + 3, 11)
j = j + 1
Loop
qdzbx = .Cells(3, 2)
qdzby = .Cells(3, 3)
End With
```

Middle pile points coordinate calculate program between Point *YH* and point *HZ* as follow.

```
Do While lc <= hz(j)
x0 = (hz(j) - lc) - (hz(j) - lc) ^ 5 / (40 * r(j) ^ 2 * ls(j) ^ 2)
y0 = (hz(j) - lc) ^ 3 / (6 * r(j) * ls(j))
If zx(j) = "Right-Turn" Then
y0 = -y0
End If
zbx = qdzbx - x0 * Cos(fwj(j)) + y0 * Sin(fwj(j))
zby = qdzby - x0 * Sin(fwj(j)) - y0 * Cos(fwj(j))
Cells(m, 4) = zbx
Cells(m, 5) = zby
m = m + 1
lc = .Cells(m, 3)
Loop
```

Pile Point Mileage and Coordinate Automatic Calculation

Within Excel, right click on menu bar above the blanks and will pop-up drop-down menu, then select "Visual Basic". Called Visual Basic menu bar displays as shown in Figure 4. Then click control toolbox shown in Figure 5 and choose command button again to insert command button which mainly used for running program when mouse click. Right click command button→command button→object→editor and enter the button name. This example adds "pile mileage calculation" and "pile coordinates calculation" two buttons. Double click the two buttons respectively and enter code editor area to insert corresponding program code. After the completion of the program editor, click the "exit design patterns" to return Excel spreadsheet and then click the button to correspond calculation. The calculation results are shown in Figure. 6.

Fig.4. Visual Basic menu

Fig.5. Control Toolbox

	A	B	C	D	E	F	G	H
1		Mileages stake number	Route mileage	Middle pile coordinate				
2				N (X)	E (Y)			
3	Origin	K000+000.000	0.000	3000.000	3000.000	Mileage calculation of stake number		
4		K000+020.000	20.000	3005.153	3019.325			
5		K000+040.000	40.000	3010.307	3038.649			
6		K000+060.000	60.000	3015.460	3057.974	Coordinate calculation of stake num		
7		K000+080.000	80.000	3020.613	3077.299			
8		K000+100.000	100.000	3025.766	3096.623			
9		K000+120.000	120.000	3030.920	3115.948			
10		K000+140.000	140.000	3036.073	3135.273			
11		K000+160.000	160.000	3041.226	3154.598			
12		K000+180.000	180.000	3046.379	3173.922			
13		K000+200.000	200.000	3051.533	3193.247			
14	ZH1	K000+214.719	214.719	3055.325	3207.469			
15		K000+220.000	220.000	3056.684	3212.572			
16		K000+230.000	230.000	3059.231	3222.242			
17		K000+240.000	240.000	3061.696	3231.934			
18		K000+250.000	250.000	3064.026	3241.658			
19		K000+260.000	260.000	3066.167	3251.426			
20		K000+270.000	270.000	3068.064	3261.244			

Sheet1 Sheet2 Sheet3 Sheet4

Fig.6. Pile mileage calculation and Pile coordinates calculation

Practices have proved that establishing calculation model according the measurement known data can effectively solve the problem and improve work efficiency in practical work. Due to the limitation of space, cannot give whole program source code, the rest of the program are the same with the design principle of part of given program.

Jilin province higher education teaching reform research subject: research on practice innovation ability training mode of civil engineering applied undergraduates.

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