A STUDY OF SPIRAL TRANSITION CURVES AS RELATED TO THE VISUAL QUALITY OF HIGHWAY ALIGNMENT

by

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INTRODUCTION

The American Association of State Highway Officials' Policy on Geometric Design states that "the appearance aspect of superelevation runoff largely governs its length" (1) when referring to spirals (transition curves) and their use. Likewise, Pushkarev (2) proposes "that a frankly esthetic approach to transition curves is justified, with their length determined not by psuedo-utilitarian minima, but rather by what is visually necessary to achieve a generous, free-flowing continuity of alignment."

Cron (3) adds to this by an analogy to the railroad designer.

> The railroad locators liked to alternate right and left curves, but were also careful to keep a good length of tangent between them. This left ample space for the later insertion of spiral transitions into the alignment. Highway designers, likewise, should provide ample tangents between curves in opposite directions, and should also provide for spirals at the beginning and ending of all but the very flattest horizontal curves. The spiral helps the driver to stay in his lane when entering or leaving a curve; it provides a convenient and mathematically correct way to superelevate or "bank" the curve; and it also greatly improves the appearance of the highway, particularly where the edges are sharply defined, as in concrete pavements. Since the application of spirals costs nothing except a little more figuring during the location survey, their use can be fully justified on aesthetic grounds alone.

Indeed, the addition of spirals to the horizontal alignment of a roadway provides a measurable visual benefit at a very small increase in cost. The main endeavor of this research was to develop criteria for the selection of spiral lengths based on the visual appearance of the curve so this benefit can be realized.

LITERATURE SEARCH

In addition to the previously mentioned references, the problem of highway alignment coordination has been recognized by numerous other authors (4, 5, 6). Most of the discussion of the problem, however, was limited to general statements concerning the visual appearance of the roadway. Although the comments were general in nature, they did point out areas of possible problems in highway alignment.

Smith and Yotter (7) utilized perspective drawings to determine the minimum acceptable length of sag vertical curves that would provide an aesthetically pleasing roadway. They also investigated the problem of a small change of direction in the horizontal alignment. Their research showed that the distance from which a curve is viewed and the angle from which it is viewed affects the appearance of the curve. Because the main concern of these researchers was the appearance of a sag vertical curve, the results of their research were of limited value in the detailed search for selection criteria of spiral curves.

T. Ten Brummelaar (8) advocates the use of deflection and curvature diagrams to determine locations which can cause discomfort or hazard in roadway design. The technique involves constructing the equivalent to shear and moment diagrams for the deflection and curvature of the roadway alignment. The shape of these diagrams will show areas which are not geometrically consistent with the adjoining sections of roadway. The use of these diagrams seems to be limited to the role of comparison of sections of one highway as no indication of the maximum allowable parameters were given.

Godin et al (5) stated that the length of spiral curve required for visual appearance exceeded both the length needed for superelevation runoff and the length needed to allow a driver to steer a smooth transition from tangent to circular curve.

Only two references contained quantitative information concerning desirable lengths of spiral curves based on the visual aspect of the roadway. Pushkarev (2) recommends that the spiral length should have a ratio to the circular curve of 1:2:1. He further states that spirals whose length becomes too great in relation to the circular curve length cause the total curve to appear to have a sharp bend in the middle. Godin (9) recommended that the minimum length of spiral curve should be R/9, where R is the limiting radius of the spiral.

In a search for additional specific, quantitative criteria concerning what constitutes a visually-pleasing highway alignment, psychology writings were investigated for a clue as to what the human eye "sees" as pleasing and for what reason. Writings on Gestalt Psychology, in particular, were examined (10,11). These investigations failed to uncover any useful quantitative results.

PURPOSE

The purpose of the research described in this paper was to determine criteria for the selection of a spiral length for horizontal curves to aid the highway designer in the creation of a visually pleasing roadway.

SCOPE

The research was limited to:

1. The horizontal curve was studied, with and without a spiral curve, to determine the relationship between the sighting distance, the geometry of the curve and the angle from which the curve is viewed.

2. The length of spiral curve necessary to provide a pleasing appearance was investigated.

METHOD OF SOLUTION

From personal observations and the information gained from the literature search, it was hypothesized that the factors affecting the visual appearance of a horizontal curve were sight distance (SD) display angle (DA) and the geometry of the curve. Sight distance is defined as the distance from the observer to the beginning of the curve, PC or TS whichever is appropriate; display angle is defined as the angle between the observer's line of sight and the plane containing the PC or TS of the curve; and the geometry of the curve is defined as the spiral length, if any, and the limiting radius of the curve. Figure 1 gives a pictorial definition of sight distance and display angle.

Due to the almost total lack of existing highways containing spiral curves as a design element, it was felt that various geometric conditions would have to be simulated to provide sufficient data for analysis of the problem of selecting spiral curve lengths for a pleasing visual appearance.

A computer algorithm (7) was available that would convert three-dimensional coordinates into two-dimensional coordinates which, when drawn, gave a perspective view. Figure 2 gives a graphic illustration of this algorithm. The three-dimensional coordinates of the roadway were used as inputs. Then, after defining the center of interest coordinates and the observer position coordinates, both in three dimensions, the two-dimensional perspective coordinates were determined by the

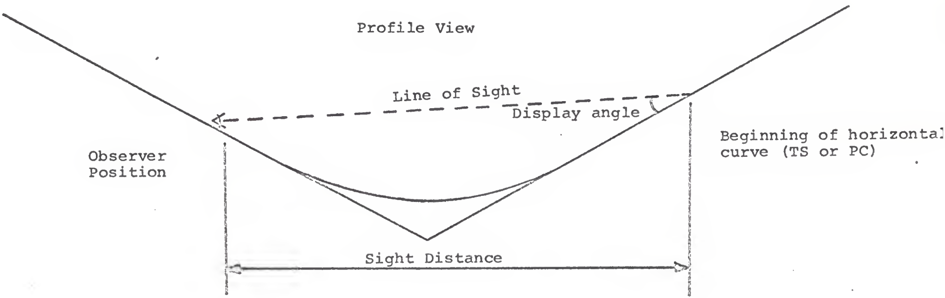
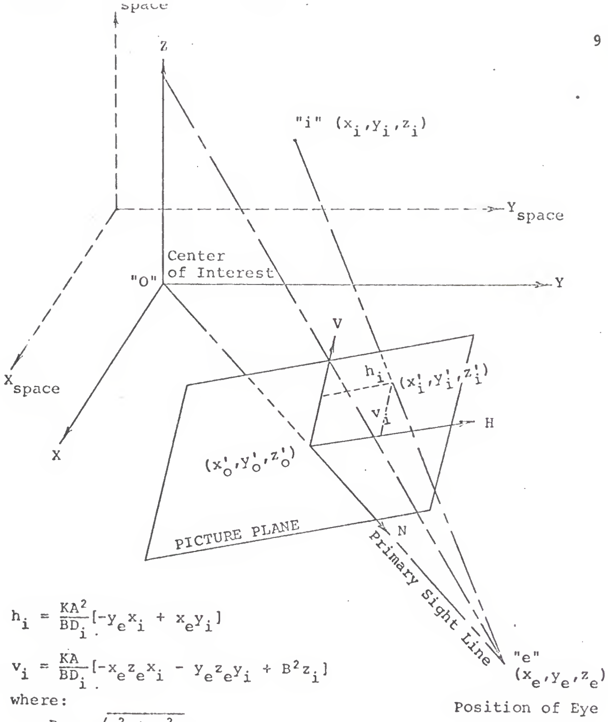


FIGURE 1. Definition of Sight Distance and Display Angle



$$h_i = \frac{KA^2}{BD_i}[-y_e x_i + x_e y_i]$$

$$v_i = \frac{KA}{BD_i}[-x_e z_e x_i - y_e z_e y_i + B^2 z_i]$$

where:

$$B = \sqrt{x_e^2 + y_e^2}$$

$$A = \sqrt{x_e^2 + y_e^2 + z_e^2}$$

$$D_i = A^2 - (x_e x_i + y_e y_i + z_e z_i)$$

K = Scale Factor, $K>0$

FIGURE 2. Perspective Coordinate Transformation

projection of the roadway coordinates on a plane perpendicular to the line of sight from the observer to the center of interest. The projections on this plane, called the picture plane, form a perspective view of the three-dimensional roadway coordinates. The equations for calculating the perspective plane coordinates are included in Figure 2. The ready access to this algorithm was instrumental in the selection of this approach to the problem of selection of spiral curve lengths for visual appearance.

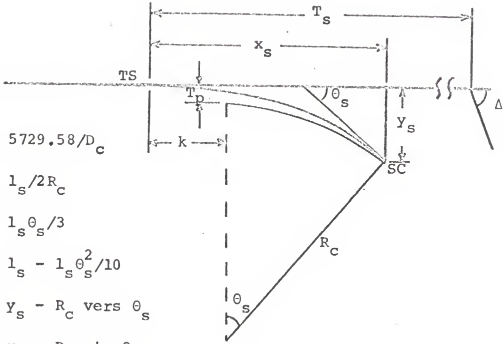
The only remaining obstacle to the utilization of this approach was the generation of the three-dimensional roadway coordinates. This was more of a problem than was originally anticipated. It was hoped that the COordinate GeOmetry (COGO) portion of the Integrated Civil Engineering System (ICES) developed by the Civil Engineering Systems Laboratory at the Massachusetts Institute of Technology (MIT) could be used to generate the three-dimensional coordinates. The ICES system (12) available for the IBM 360 computer included provision for the calculation of spiral curves. However, after discussion with computing personnel at Kansas State University and the persons in charge of ICES at MIT, it was found to be extremely difficult to secure any form of output other than the standard printed output. This would have necessitated punching all of the three-dimensional coordinates for input into the coordinate transformation program.

Therefore, it was deemed necessary to develop a computer program to generate the roadway coordinates. The equations for calculating the centerline roadway coordinates are from Hickerson's book (13) Route Surveys and Design. The spiral curve used was approximately a cubic parabola. The general equation for the spiral is $R = K/l$; where, R is the radius of the spiral at any point on the spiral, l is the distance along the spiral to the point of radius R and K is a constant. From this equation it can be shown that the radius of the spiral is infinite when $l = 0$, at the TS or beginning of the spiral curve, and decreases as l increases.

The equations used for calculation of the spiral curve are shown in Figure 3. The equations for x_s and y_s are very close approximations of the true equations, and the loss of accuracy due to these approximations was not felt to be sufficient to alter the perspective picture.

The edge of roadway and edge of shoulder coordinates were calculated by determining the centerline direction and using sine and cosine functions to locate them at a given offset distance. Again, this approximation to the true coordinates of these points was not felt to be great enough to alter the realism of the perspectives.

The resulting program allows any roadway geometrics to be simulated with a minimum of input data. It can be used to simulate a hypothetical situation or give the coordinates of an actual location. The coordinate generation program was then made a subroutine of the coordinate transformation and plotting program. The program output was a printout of the centerline geometry and data stored on a 7-track computer



$R_c = 5729.58/D_c$

$\theta_s = l_s/2R_c$

$y_s = l_s\theta_s/3$

$x_s = l_s - l_s\theta_s^2/10$

$p = y_s - R_c \text{ vers } \theta_s$

$k = x_s - R_c \sin \theta_s$

$T_s = (R_c + p)\tan 1/2\Delta + k$

R_c - limiting radius of the spiral (feet)

D_c - limiting degree of the spiral (degrees)

l_s - total length of the spiral from TS to SC

θ_s - central angle of spiral arc l_s (radians)

y_s - offset from the tangent to the spiral at the SC (feet)

x_s - tangent distance for the SC (feet)

T_s - total tangent distance (feet)

TS - point of change from tangent to spiral

SC - point of change from spiral to circle

Δ - total deflection of the curve

FIGURE 3. Spiral Curve Calculation Equations

tape which could be mounted on a Calcomp Incremental Plotter for drawing the perspective pictures. A general flow diagram of the program is presented in Figure 4. A printout of the complete program is included in the appendix.

Simulation of roadway geometry would be valid only if the perspective picture looks like the actual location. The realism of the perspective pictures can be judged by comparing the perspective drawing and photograph of the same location in Figure 5. The observer position for the perspective picture was approximately the same location from which the photograph was taken. The photograph was taken with a 35mm, NIKON F, automatic single lens reflex camera with a NIKKOR, f3.5, 43mm to 86mm Zoom lens. The lens was set at 86mm, the focal length judged to provide the most "natural" perspective. It should be noted that only the right hand lanes of the divided highway are represented in the perspective drawing, since there was no provision for drawing a divided highway in the original program.

Approximately five-hundred perspective pictures were plotted with varying sight distances, limiting degree of curve, spiral length and display angle. For any given set of geometric conditions, the sight distance and display angle were varied by moving the observer position. Moving the observer up into space above the roadway created artificial display angles and simulated the case where a sag vertical curve is located between the observer and the horizontal curve without the disruptive element caused by the vertical curve. It was felt that

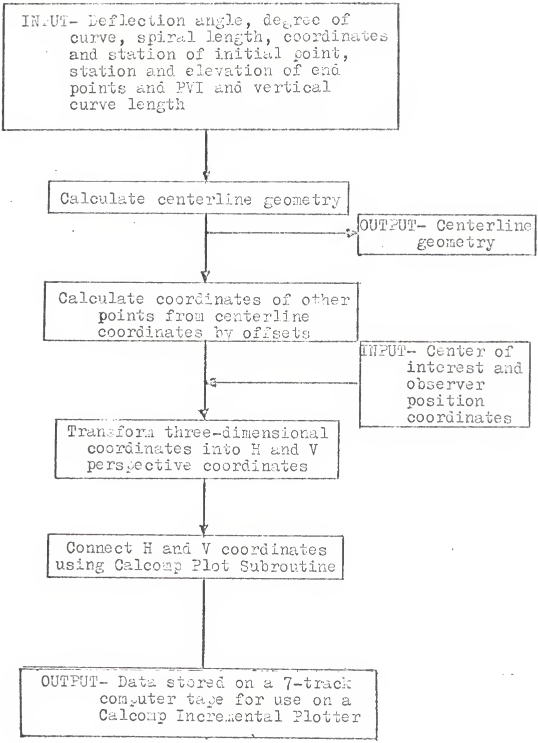


FIGURE 4. Flow Chart

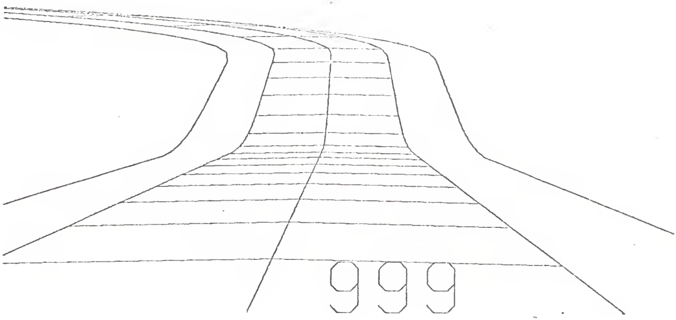


FIGURE 5. Photograph and Perspective of Selected Location

if a vertical curve had been used to create a display angle, the appearance of the horizontal curve might be affected by the vertical curve, thus creating a problem of alignment coordination.

A wide range of geometric conditions was investigated. The degree of curve was varied from 30 minutes to 5 degrees. Some of the curves were constructed without a spiral transition so that the visual effect of adding a spiral curve could be tested. The spiral lengths varied from 100 to 2000 feet. An attempt was made to select lengths which would test the theories proposed by Godin and Pushkarev. The lengths of spirals examined at each limiting degree of curve are shown in Table 1.

All curves were rated according to their smoothness of appearance and the rate at which they seemed to diverge from the tangent. The rating scale was: acceptable, questionable or unacceptable. Although this may seem a crude rating scale, it was felt that any refinement beyond this level was not justified because at some point the decision had to be made whether a curve was acceptable or unacceptable.

TABLE 1. Geometry of Locations Studied.

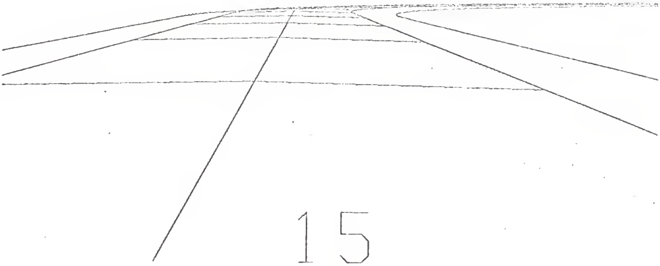
Spiral Lengths Tested for Each Degree of Curve					
0.50°	1°	2°	3°	4°	5°
0.	0.	0.	0.	0.	0.
500.	250.	300.	200.	200.	100.
2000.	500.	500.	600.	500.	400.
	1000.				
	2000.				

RESULTS

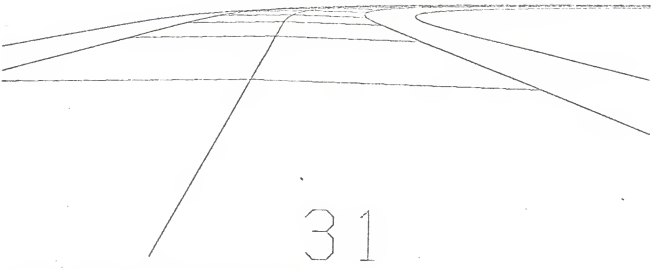
One important point discovered while investigating the problem of apparent divergence of a horizontal curve from the tangent was that when the observer is only a small distance, such as 3.5 feet, above the plane of the curve, nothing can be done to make the roadway appear smooth. The two perspectives shown in Figure 6 illustrate this point. Perspective 15 (Fig. 6A) is a one degree circular curve that traverses a ten degree deflection. Perspective 31 (Fig. 6B) is the same location but a one-thousand foot spiral, resulting in a completely spiralized curve, was used in place of the circular curve. A small difference in the curves can be detected, but neither curve was judged to be visually acceptable.

However, as the observer is raised above the plane of the curve, an increasing display angle, the addition of spiral curves to the horizontal alignment does result in an observable improvement in the appearance of the curve. The effect of different spiral curves can be observed in Figures 7 and 8. The sight distance and display angle are constant for all perspectives. The length of spiral curve is the only variable. Perspective 315 is a circular curve with no spiral. Perspective 323 has a 250 foot spiral and perspectives 315 and 331 have 500 and 1000 foot spirals, respectively. Note the increased smoothness of curve from perspectives 315 through 331.

The proposal by Pushkarev (2) that a completely spiraled curve will appear to have a sharp bend in the middle was investigated. The perspectives in Figures 7 and 8 illustrate

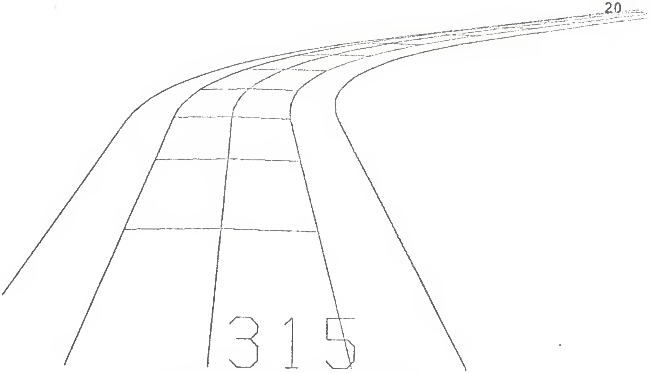


A. No Spiral (Circular Curve)

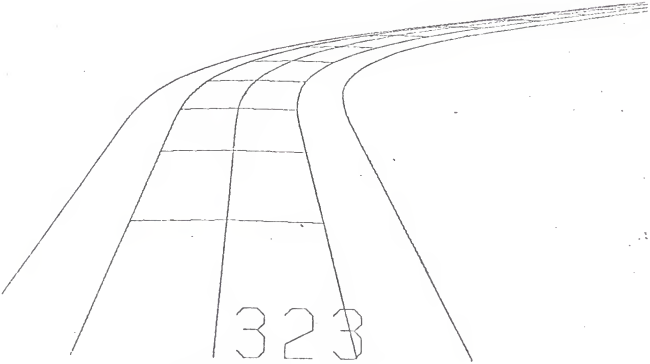


B. Completely Spiralized

FIGURE 6. Effect of Spiral Curves at Small Display Angles



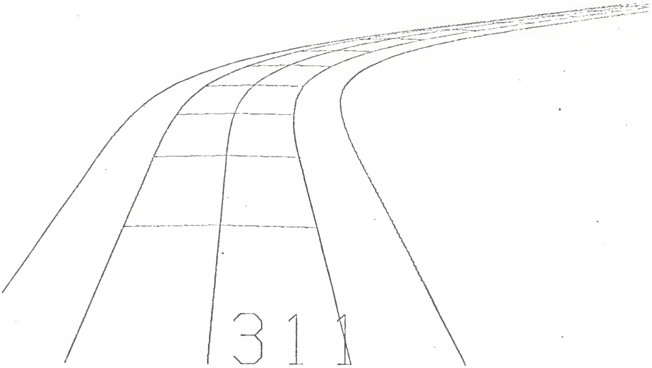
A. No Spiral (Circular Curve)



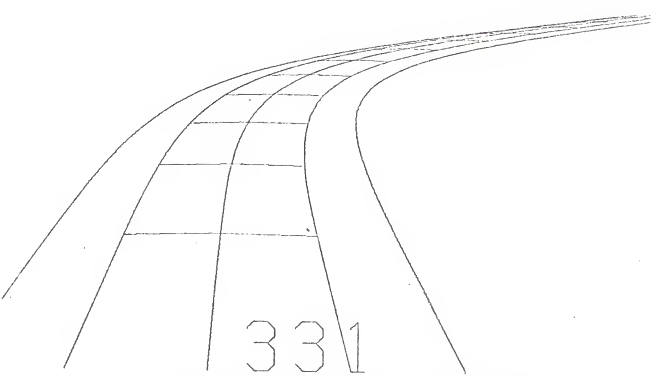
B. Spiral Length = 250 Feet

FIGURE 7. Effects of Spiral Curves (DA = .015 Radians, SD = 1000 Feet, D = 1° and Δ = 10°)

Plate 1



A. Spiral Length = 500 Feet



B. Spiral Length = 1000 Feet (Completely Spiralized)

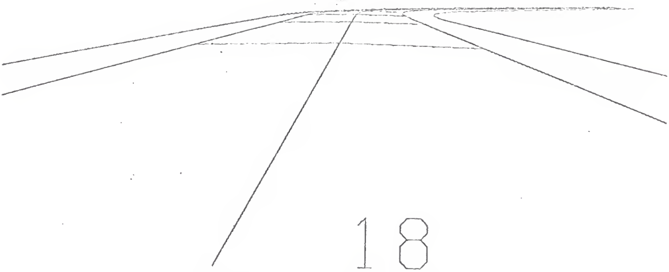
FIGURE 8. Effects of Spiral Curves (DA = .015 Radians, SD = 1000 Feet, D = 1° and Δ = 10°)

Plate 2

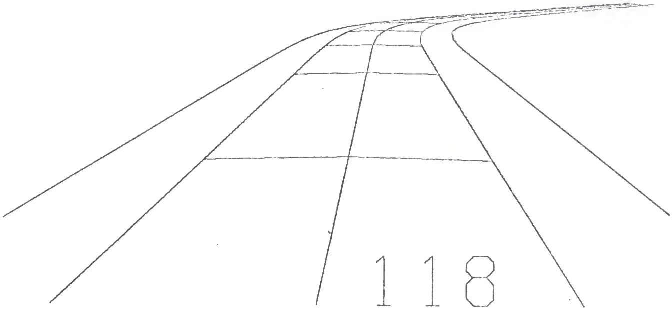
that, contrary to appearing sharp, the completely spiraled curve appears smoothest of all the curves. Therefore, it may be concluded that the length of spiral curve needed at any given location is not related to the ratio of spiral curve to circular arc. There are two cases, however, which were not investigated. The first is when a vertical curve is superimposed on the spiral, a problem beyond the scope of this research, and the case where the observer is located on the curve and views the junction of the two spirals.

An investigation was also undertaken to determine if Godin's recommendation of a spiral length of R/9 was valid. As was pointed out in the previous paragraph, the appearance of any given curve improved with additional length of spiral added. The recommendation to use a length of spiral equal to R/9 is further limited because no mention is made of the display angle. However, for almost all sight distances and display angles, it was felt that this recommendation resulted in a spiral length that was not sufficient to be visually significant.

The effects of various display angles were studied to determine the extent that they affect the appearance of a curve. Figures 9 and 10 pictorially show how the display does affect the appearance of a curve. All perspectives had the same geometry and sight distance. The display angles for each curve are listed with the figure. Note that as the display angle increases, the appearance of the curve improves.

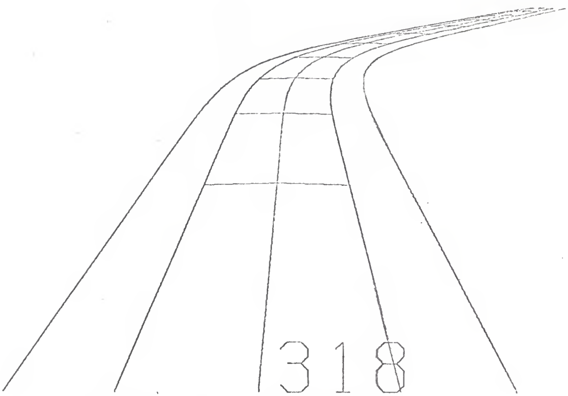


A. Display Angle = .007 Radian

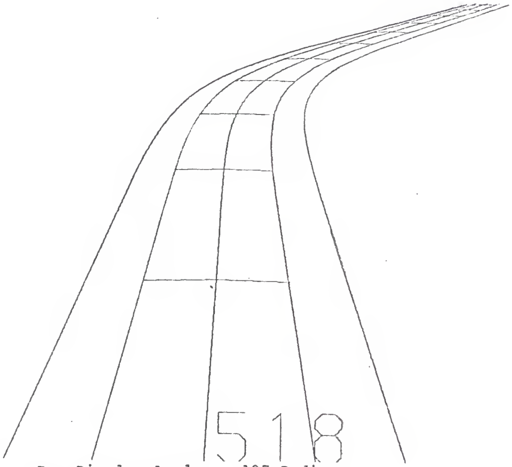


B. Display Angle = .027 Radian

FIGURE 9. Effects of Display Angle ($D = 2°$, $\Delta = 10°$, $l_s = 500$ feet, SD = 500 feet)
Plate 1



A. Display Angle = .067 Radian



B. Display Angle = .107 Radian

FIGURE 10. Effects of Display Angle ($D = 2°$, $\Delta = 10°$, $l_s = 500$ feet, SD = 500 feet)
Plate 2

An attempt was made to construct a graph showing the relationship between sight distance, display angle and the geometry of the curve. However, the wide range of variables used made it extremely difficult to formalize any sort of graph including all of the variables. Figure 11 is a graph illustrating the relationship between sight distance and length of spiral when the display angle and degree of curve are held constant. The display angle and degree of curve for this graph were chosen so that the number of available data points used would be a maximum. A quadratic curve was chosen because it was felt that at long sight distances no spiral would be visually acceptable.

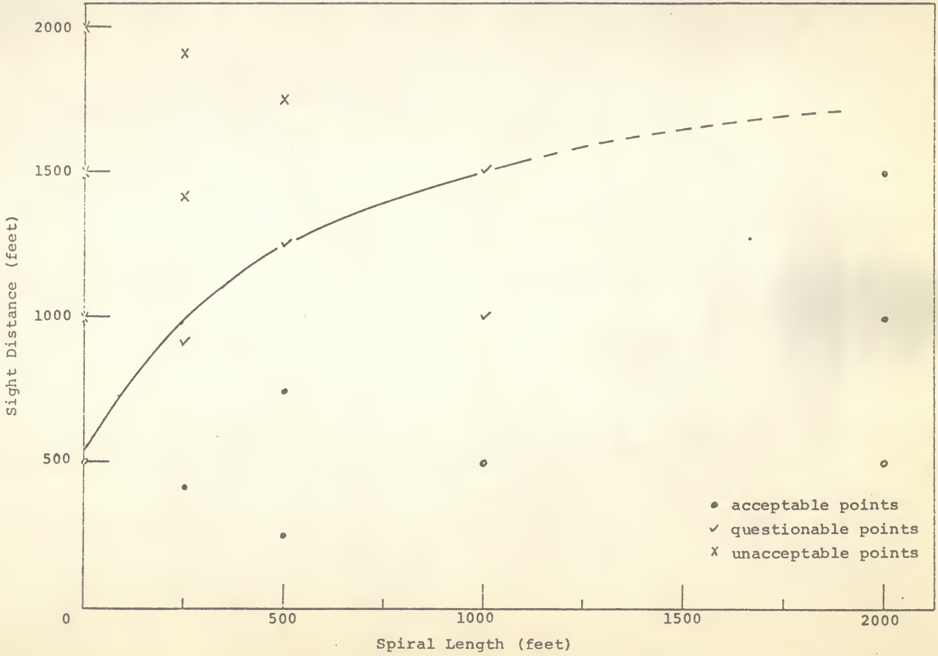


FIGURE 11. Sight Distance Versus Spiral Length (DA = .02 Radians, D = 1°)

RECOMMENDATIONS FOR FURTHER RESEARCH

Late in the research, while discussing the problem of determining what gives any given curve a bad appearance with my major professor, Dr. Bob L. Smith, it was brought out that the amount of curvature or sharpness of curvature of a curve in the perspective picture plane should be a good indicator of the appearance of that curve. After all, that is exactly what had been done to evaluate the perspectives, i.e. visually measuring the sharpness of the curves. It was decided, therefore, to attempt to use the change of slope in the perspective picture plane as a means of predicting the appearance of the curves. Subsequent discussion made it seem that the rate of change of slope of the curves in the perspective picture plane would be of more value.

A Fortran computer program was prepared that would convert the points of a curve into the perspective picture plane coordinates and calculate the slope between each of the adjacent points. The change of slope between adjacent slopes was then calculated and the rate of change of slope obtained by dividing the change of slope by the average picture plane distance of the two slopes. From the output, change of slope and rate of change of slope, it was hoped to obtain a rate of change of slope, such that, any rate of change greater than the critical rate would not have an acceptable appearance. Only the maximum rate of change for each curve was investigated as this was thought to be the critical point, visually, of the curve.

The initial trial of this hypothesis resulted in unanticipated results. For any given sight distance and curve, the maximum rate-of-change of slope decreased as the appearance of the curves improved, as was expected. However, for a given viewing angle, the relationship did not give the anticipated result. As the sight distance increased, the rate of change of the slope decreased while the appearance of the curve was becoming poorer. Inspection of the change of slopes revealed they did give the relationships which were expected from the rate of change of slope.

After further study, the situation was explained by the fact that the points were all located at equal spacings in the space (x,y,z) coordinate system and, therefore, the changes of slope were actually rates of change. The calculated rates of change from the computer program were calculated from the picture plane distance. Although the points were equal distance apart in the space coordinate system, the coordinate transformation into a perspective view made the picture plane distance of the points near the observer greater than the distance of the points further from the observer. Therefore, the changes of slope of the near points were divided by a larger number than the more distantly located points. However, the nature of a perspective picture is such that an observer sees all the points as being separated by an equal distance when, in fact, this is not the physical case in the picture plane.

Figure 12 is an illustration showing the logic of using the rate of change of slope to determine the visual appearance of a curve. Slope lines were drawn through corresponding points of each perspective. It can be observed, however, that the change of slope is greater for the unacceptable curve than for the acceptable one. By increasing the frequency of the calculation of the slope lines to the extent that every defined point is the end point of a slope line, the rate of change of slope can be calculated for each point and the maximum value selected for comparison to the critical value.

Table 2 shows the values obtained when this approach was tested. All of the calculations were made using the geometry of one curve; D = 30 minutes, Δ = 20 degrees and length of spiral = 2000 feet. It can be noted that the numerical values obtained were extremely well segregated into the three visual classifications used for rating these curves.

This approach is not restricted to points which are equally spaced in three dimensions, however. The complexity of the coordinate transformation requires the use of a digital computer and it is a small matter for a computer to calculate the distance between the points in three dimensions. By dividing the change of slopes by half the total distance of the two slope lines, a rate of change of slope can be calculated. If this rate of change is less than the critical value, the curve will appear smooth when constructed in three dimensions. Conversely, if the rate of change is greater than the critical

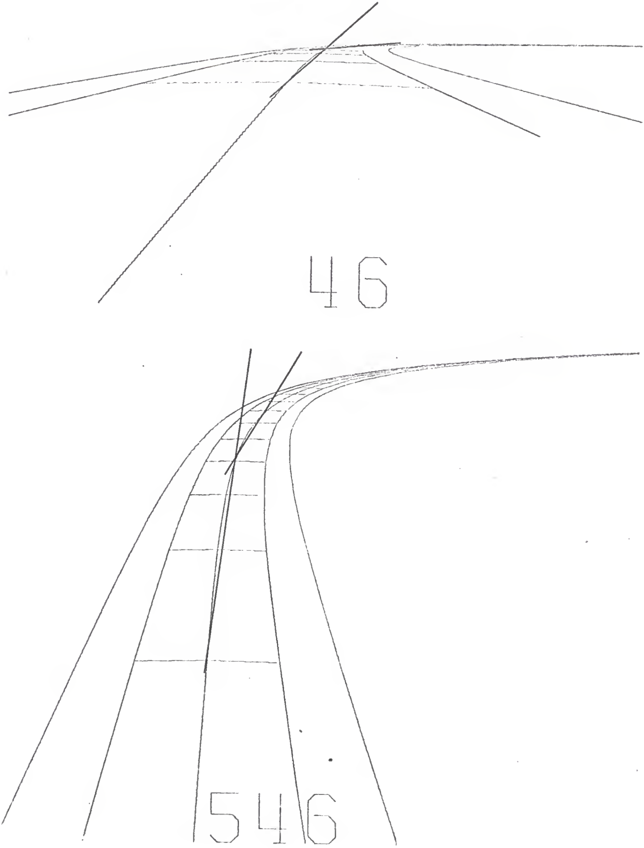


FIGURE 12. Illustration of Rate of Change of Slope

TABLE 2. Rates of Change of Slope Versus Curve Ratings

Acceptable	Questionable	Not Acceptable
2.8	3.1	10.6
1.6	3.4	11.7
1.8	2.2	13.2
2.0	3.8	14.6
1.1		
1.2		
1.4		
1.5		
.7		
1.0		
.7		
1.0		
.7		
1.2		
.8		

value, the three-dimensional curve will appear sharp and "jerk" away from the tangent.

The preliminary investigation was undertaken with the observer stationed three feet to the right and 3.5 feet above the centerline with the centerline used as the line from which the slopes were calculated. Use of any other line, such as one of the edge of pavement lines, would be valid provided the observer is located in the same relative position. The center of interest was on the centerline approximately at the beginning of the curve. The location of the center of interest is not as critical to the analysis of rate of change of slope as is the observer position.

In recommending this particular area of study for additional research, it should be pointed out that the basic concept of using the rate of change of slope in the picture plane seems to be very logical and straight-forward. Whether the formulation presented in this thesis is entirely valid or not can only be proven by additional testing. However, it is felt that this method for determining the visual acceptance of a curve holds great promise.

CONCLUSION

From the limitations imposed by the scope of this study and from the data collected, the following was concluded:

1. Spiral curves do improve the appearance of most circular curves.

2. When the observer is near the plane of the curve, there is no significant difference in the appearance of a spiraled and an unspiraled curve.

3. As the distance from the curve to the observer increases, the length of spiral needed increases for good visual quality.

4. As the height of the observer raises above the plane of the curve, increasing display angle, the length of spiral needed decreases for good visual quality.

5. Curves which consist entirely of spiral curves give the best visual appearance, all other conditions being equal.

6. The rate at which a curve visually appears to diverge from the tangent affects the visual quality of the curve.

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APPENDIX

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$JOB          JSM,RUN=CHECK,TIME=15,PAGES=300
C     MAIN PROGRAM
      DIMENSION X(15,90),Y(15,90),Z(15,90),H(15,90),V(15,90)
      DIMENSION NSKIP(18),BUFF(2000)
      COMMON /CL/ XY1(90),XY2(90),STA(100)
C     NSKIP(16)=KEY
C     NSKIP(17)=ISKIP
C     NSKIP(18)=WRITE H AND V
      CALL PLOTS (BUFF,2000)
      CALL PLOT (0.,0.,-3)
      READ (1,902) LOC,MODE
C   * SUBROUTINE CLGM CONTAINS READ STATEMENTS
    1 CALL CLGM (X,Y,Z,N,KEY,NSKIP(17))
      IF(N)899,899,101
  101 IF(KEY) 899,102,103
  102 CALL OFRD2 (X,Y,Z,N)
      LINE=5
      NCL=1
      GO TO 66
  103 IF(KEY-6) 104,104,79
  104 GO TO (70,71,72,73,74,75),KEY
   70 CALL OFRD2 (X,Y,Z,N)
      DO 80 I=1,N
      X(7,I)=X(1,I)
      Y(7,I)=Y(1,I)
   80 Z(7,I)=Z(1,I)
      CALL OFLN (X,Y,Z,STA,N,KEY)
      LINE=6
      NCL=7
      GO TO 66
C     KEY=4--FOUR LANE ROAD WITH BACKSLOPE INFLECTION POINTS GIVEN
   73 CALL OF4L (X,Y,Z,N)
      CALL OFLN (X,Y,Z,STA,N,KEY)
      LINE=12
      NCL=13
      GO TO 66
   71 CONTINUE
   72 CONTINUE
   74 CONTINUE
   79 WRITE (3,640) KEY
      GO TO 899
C   * SUBROUTINE OFLN2 CONTAINS A READ STATEMENT
   75 CALL OFLN2 (X,Y,Z,N)
      LINE=6
      NCL=9
   66 IF(MODE) 68,68,67
   67 WRITE (3,201)
      WRITE (3,200) ((STA(I),X(K,I),Y(K,I),Z(K,I),K,I,K=1,LINE),I=1,N)
C   * READ NUMBER OF OBSERVER POSITIONS
   68 READ (1,902) NOPS
C
C     READ FORMAT
  900 FORMAT(3F10.2)
  901 FORMAT(I5,3F10.2,I5)
  902 FORMAT(2I5)
C
C     WRITE FORMATS
  200 FORMAT(2(4F10.2,2I6,10X))
  201 FORMAT(2(10H   STATION,7X,1HX,9X,1HY,9X,1HZ,7X,1HK,5X,1HI,10X)/)
  620 FORMAT(1H1,16X,13H**PLOT NUMBER,I7,2H**/17X,22(1H*)//)
```

```
  622 FORMAT(1H ,5X,16HVANISHING POINTS,11X,5HHORZ.,11X,5HVERT.)
  624 FORMAT(10X,6HX-AXIS,8X,F14.3,3X,F14.3)
  626 FORMAT(10X,6HY-AXIS,8X,F14.3,3X,F14.3)
  628 FORMAT(10X,6HZ-AXIS,8X,F14.3,3X,F14.3)
  630 FORMAT(///12X,30HCENTER OF INTEREST COORDINATES/21X,3HX =,F9.2/21
     1,3HY =,F9.2/21X,3HZ =,F9.2//12X29HOBSERVER POSITION COORDINATES,/
     21X,3HX =,F9.2/21X,3HY =,F9.2/21X,3HZ = F9.2)
  632 FORMAT(2(9X,2I8,1X,2F13.2,9X))
  634 FORMAT(15X,16HSIGHT DISTANCE =,F8.0/)
  636 FORMAT(1X,10(1H*),47HINVALID VALUE FOR CENTER OF INTEREST STATION
     10F,F15.2)
  638 FORMAT(11H END OF RUN)
  640 FORMAT(16H ERROR *** KEY =,I10)
  642 FORMAT(1H-)
      SCALE=0.10
      NSKIP(16)=KEY
C   * READ CENTER OF INTEREST STATION
      READ (1,903) XO,YO,ZO,IDCI
  903 FORMAT(3F10.2,I5)
      IF(IDCI)4,4,3
    4 CISTA=XO
      DO 8 I=1,N
      IF(STA(I)-CISTA) 8,7,7
    8 CONTINUE
      WRITE (3,636) CISTA
      GO TO 899
    7 XO=X(NCL,I)
      YO=Y(NCL,I)
      ZO=Z(NCL,I)
C   * READ OBSERVER POSITION COORDINATES
    3 READ (1,901) NPLOT,XEP,YEP,ZEP,NSKIP(18)
      WRITE (3,620) NPLOT
      SD=SQRT((XEP-XO)**2+(YEP-YO)**2)
      WRITE (3,634) SD
C     CALCULATE CONSTANTS
      XE=XEP-XO
      YE=YEP-YO
      ZE=ZEP-ZO
      B2=XE*XE+YE*YE
      B=SQRT(B2)
      A2=B2+ZE*ZE
      A=SQRT(A2)
C     CALCULATE VANISHING POINTS
      WRITE (3,622)
      VH=SCALE*A2*YE/(B*XE)
      VV=SCALE*A*ZE/B
      WRITE (3,624) VH,VV
      VH=-SCALE*A2*XE/(B*YE)
      WRITE (3,626) VH,VV
      VH=0.0
      VV=-SCALE*A*B/ZE
      WRITE (3,628) VH,VV
      WRITE (3,630) XO,YO,ZO,XEP,YEP,ZEP
      DO 20 I=1,LINE
      NSKIP(I)=0
      DO 20 J=1,N
      XX=X(I,J)-XO
      YY=Y(I,J)-YO
      ZZ=Z(I,J)-ZO
      D=A2-(XE*XX+YE*YY+ZE*ZZ)
```

```
      IF(D) 5,5,10
    5 NSKIP(I)=NSKIP(I)+1
      H(I,J)=0.
      V(I,J)=0.
      GO TO 20
   10 H(I,J)= SCALE*A2/(B*D)*(XE*YY-YE*XX)
      V(I,J)=SCALE*A/(B*D)*(B2*ZZ-ZE*(XE*XX+YE*YY))
   20 CONTINUE
      IF(NSKIP(18)-1) 60,60,50
   50 WRITE (3,642)
      DO 40 I=1,LINE
      NN=NSKIP(I)+1
   40 WRITE (3,632) (I,J,H(I,J),V(I,J),J=NN,N)
   60 PLOTN=NPLOT
      CALL NUMBER (+5.,0.,1.,PLOTN,90.0,-1)
      CALL DRAW (LINE,N,H,V,NSKIP)
      CALL PLOT (12.,0.,-3)
      NOPS=NOPS-1
      IF(NOPS) 30,30,3
   30 LOC=LOC-1
      IF(LOC) 898,898,1
  898 CALL PLOT ( 0.,0.,999)
      WRITE (3,638)
  899 STOP
      END
```

```
      SUBROUTINE CLGM (XX,YY,ZZ,NN,KEY,ISKIP)
C     MAIN SUBROUTINE FOR CENTERLINE COORDINATES
C
C     READ FORMATS
  900 FORMAT(10I5)
  901 FORMAT(6F10.2)
  902 FORMAT(I3,F10.2)
  903 FORMAT(3F5.0,F3.0,F6.2)
  904 FORMAT(F5.0,F3.0,F6.2,6X,F5.0,F3.0,F6.2)
C
C     WRITE FORMATS
  925 FORMAT(53X,31HEND OF ROADWAY GEOMETRY PROGRAM//)
  926 FORMAT(34X,70H*****************************************************
     -*****************//)
  940 FORMAT(1H1)
  945 FORMAT(/////)
  949 FORMAT(1H1/////////)
  950 FORMAT(10X,49H*** ALIGNMENT SIZE EXCEEDS DIMENSIONED STORAGE BY,I2
     1)
  951 FORMAT(5X,54HWARNING *** NUMBER OF POINTS MAY EXCEED DIMENSION SIZ
     1E)
  952 FORMAT(10X,62HTHE TANGENT DISTANCE BETWEEN TWO SUCCESSIVE CURVES I
     1S NEGATIVE)
  953 FORMAT(1H+,100X,17HTANGENT DIRECTION,F14.2)
  954 FORMAT(1H1,27X,25HHORIZONTAL CURVE GEOMETRY/////)
  955 FORMAT(28X,23HVERTICAL CURVE GEOMETRY/////)
  956 FORMAT(1H1,47X,9HTHERE ARE, I3,24H POINTS IN THE ALIGNMENT)
  957 FORMAT(50X,22HSTATION OF FIRST POINT,F10.2)
  958 FORMAT(50X,21HSTATION OF LAST POINT,F11.2)
  959 FORMAT(10X,5(1H*),38H INVALID CROSS SECTION INDICATOR VALUE )
  960 FORMAT(36X,5HCURVE,I3)
  961 FORMAT(36X,8H********)
  962 FORMAT(1H1,30X,19HCENTERLINE GEOMETRY/)
  963 FORMAT(17X,I5,4F10.2)
  964 FORMAT(21X,1HI,6X,1HX,9X,1HY,9X,1HZ,8X,3HSTA)
  973 FORMAT(///////////)
  974 FORMAT(101X,23HDISTANCE BETWEEN CURVES,F8.2)
  975 FORMAT(101X,14HTANGENT LENGTH,F17.2)
  976 FORMAT(//48X,23HCROSS LINES DRAWN EVERY,F8.0,5H FEET/48X,24HPOINTS
     1 ARE DEFINED EVERY,F7.0,5H FEET)
C
C     COMMON AND DIMENSION STATEMENTS
      DIMENSION XX(15,90),YY(15,90),ZZ(15,90),Z(100)
      DIMENSION SPIR(10),DEFL(10),TANL(11)
      COMMON/CL/X(90),Y(90),STA(100)
      COMMON/RD1/ DIST,I,N,NDEFL(10),RDEFL(10),DC(10)
C
C
C     READ DATA AND INITIALIZE VALUES
      DO 1 I=1,10
    1 SPIR(I)=0.
      DO 110 I=1,60
  110 STA(I)=0.0
C   * READ NUMBER OF PIS(NPHI) AND PVIS(NPVI)
      READ (1,900) NPHI,NSPIR,NPVI,KEY
C   * READ DISTANCE BETWEEN POINTS AND INITIAL DIRECTION FROM NORTH
      READ (1,903) DIST,XDIST,A,B,C
      THETA=(A+B/60.+C/3600.)*0.0174533
      NTAN=NPHI+1
      IF(XDIST-DIST) 109,117,115
```

```
  109 XDIST=DIST
  117 ISKIP=1
      GO TO 116
  115 ISKIP=XDIST/DIST
      XDIST=DIST*FLOAT(ISKIP)
  116 IF(10-NPHI)100,101,101
  100 IXCES=NPHI-10
      WRITE (3,950) IXCES
      GO TO 899
  101 IF(8-NPVI) 106,105,105
  106 IXCES=NPVI-8
      WRITE (3,950) IXCES
      GO TO 899
C   * READ COORDINATES OF INITIAL POINT AND STATION
  105 READ (1,901) X(1),Y(1),STA(1)
C     DIRECTION CHANGES ARE READ AS DEFLECTIONS
C     CLOCKWISE IS POSITIVE AND COUNTERCLOCKWISE IS NEGATIVE
C   * READ DEFLECTION ANGLES (DEFL) AND DEGREES OF CURVE (DC)
      DO 107 I=1,NPHI
      READ (1,904) A,B,C,D,E,F
      IF(A) 112,113,113
  112 DEFL(I)=A-B/60.-C/3600.
      GO TO 114
  113 DEFL(I)=A+B/60.+C/3600.
  114 DC(I)=D+E/60.+F/3600.
  107 CONTINUE
C   * READ TANGENT LENGTHS
      READ (1,901) (TANL(I),I=1,NTAN)
      TOTAL=0.
      DO 102 I=1,NTAN
  102 TOTAL=TOTAL+TANL(I)
      NTOT=TOTAL/DIST
      IF(NTOT-90)111,111,103
  103 WRITE (3,951)
  111 DO 104 I=1,NPHI
      RDEFL(I)=DEFL(I)*.0174533
      NDEFL(I)=1
      IF(DEFL(I))108,104,104
  108 NDEFL(I)=-1
      DEFL(I)=-DEFL(I)
  104 CONTINUE
      IF(NSPIR)211,210,211
C   * READ SPIRAL CURVE NUMBER AND LENGTH
  211 READ (1,902) (N,SPIR(N),I=1,NSPIR)
C
C
C     MAIN ROUTINE FOR CENTERLINE COORDINATES
  210 T2=0.
      TD1=0.
      N=2
      S1=0.
      I=1
      WRITE (3,954)
      GO TO 97
   99 I=I+1
      DHETA=THETA*57.3
      WRITE (3,953) DHETA
   97 IF(SPIR(I))3,3,4
C
C     PRELIMINARY CIRCULAR CURVE CALCULATIONS
```

```
    3 IF(NTAN-I)20,20,22
   20 TD2=0.
      GO TO 23
   22 TD2=5729.58*TAN(.0087267*DEFL(I))/DC(I)
   23 TT=T2
      TB=TANL(I)-TD1-TD2
      WRITE (3,974) TB
      WRITE (3,975) TD2
      IF(TB+10.)209,2,2
  209 WRITE (3,952)
      GO TO 899
    2 IF(T2)6,6,27
   27 X(N)=PTX+T2*SIN(THETA)
      Y(N)=PTY+T2*COS(THETA)
      STA(N)=PTS+T2
      N=N+1
    6 IF(TB-DIST)17,8,8
    8 TT=TT+DIST
      IF(TT-TB)5,7,7
    5 X(N)=X(N-1)+DIST*SIN(THETA)
      Y(N)=Y(N-1)+DIST*COS(THETA)
      STA(N)=STA(N-1)+DIST
      N=N+1
      GO TO 8
   17 C1=DIST-TB
      D1=TB
      GO TO 9
    7 C1=TT-TB
      D1=DIST-C1
    9 ANGLE=THETA
      PCX=X(N-1)+D1*SIN(THETA)
      PCY=Y(N-1)+D1*COS(THETA)
      PCS=STA(N-1)+D1
      IF(I-NPHI)18,18,799
   18 WRITE (3,940)
      WRITE (3,945)
      WRITE (3,960) I
      WRITE (3,961)
      CALL CIRCLE (C1,ANGLE,T2,DEFL(I),PCX,PCY,PTX,PTY,PCS,PTS)
      THETA=THETA+RDEFL(I)
      TD1=TD2
      GO TO 99
C
C     PRELIMINARY SPIRAL CURVE CALCULATIONS
    4 IF(NTAN-I)24,24,25
   24 TD2=0.
      GO TO 26
   25 RC=5729.58/DC(I)
C     THES IS IN RADIANS
      THES=SPIR(I)/(2.*RC)
      YS=SPIR(I)*THES/3.
      XS=SPIR(I)-(SPIR(I)*THES**2/10.)
      P=YS-RC*(1.-COS(THES))
      DK=XS-RC*SIN(THES)
      TD2=(RC+P)*TAN(.0087267*DEFL(I))+DK
   26 TB=TANL(I)-TD1-TD2
      WRITE (3,974) TB
      WRITE (3,975) TD2
      TT=T2
      IF(TB+10.)10,11,11
```

```
   10 WRITE (3,952)
      GO TO 899
   11 IF(T2)28,28,29
   29 X(N)=PTX+T2*SIN(THETA)
      Y(N)=PTY+T2*COS(THETA)
      STA(N)=PTS+T2
      N=N+1
   28 IF(TB-DIST)21,12,12
   12 TT=TT+DIST
      IF(TT-TB)13,14,15
   13 X(N)=X(N-1)+DIST*SIN(THETA)
      Y(N)=Y(N-1)+DIST*COS(THETA)
      STA(N)=STA(N-1)+DIST
      N=N+1
      GO TO 12
   21 S1=DIST-TB
      GO TO 16
   15 S1=TT-TB
      GO TO 16
   14 S1=0.
   16 ANGLE=THETA
      IF(I-NPHI)19,19,799
   19 WRITE (3,940)
      WRITE (3,960) I
      WRITE (3,961)
      CALL SPIRAL (S1,ANGLE,T2,SPIR,THES,PTX,PTY,PTS)
      THETA=THETA+RDEFL(I)
      TD1=TD2
      GO TO 99
  799 N=N-1
      WRITE (3,956) N
      WRITE (3,957) STA(1)
      WRITE (3,958) STA(N)
      WRITE (3,976) XDIST,DIST
      WRITE (3,940)
      WRITE (3,955)
C   * SUBROUTINE VERT CONTAINS READ STATEMENTS
      CALL VERT (NPVI,N,STA,Z)
      WRITE (3,962)
      WRITE (3,964)
      DO 30 I=1,N
   30 WRITE (3,963) I,X(I),Y(I),Z(I),STA(I)
      IF (KEY) 31,32,33
   31 WRITE (3,959)
      WRITE (2,963) N
      WRITE (2,963) (I,X(I),Y(I),Z(I),STA(I),I=1,N)
      GO TO 899
   32 J=1
      GO TO 34
   33 IF(KEY-1) 32,32,35
   35 J=9
   34 DO 920 I=1,N
      XX(J,I)=X(I)
      YY(J,I)=Y(I)
  920 ZZ(J,I)=Z(I)
  999 WRITE (3,949)
      WRITE (3,926)
      WRITE (3,925)
      WRITE (3,926)
      WRITE (3,940)
```

```
      NN=N
      RETURN
  899 NN=0
      RETURN
      END
```

```
      SUBROUTINE OFRD2 (X,Y,Z,NPPL)
      DIMENSION X(15,90),Y(15,90),Z(15,90)
      DO 10 I=1,NPPL
      X(9,I)=X(1,I)
   10 Y(9,I)=Y(1,I)
      NLINE=5
      NM1=NPPL-1
      DO 50 K=2,NLINE
      D=-22.0
      IF(K.EQ.3) D=-12.0
      IF(K.EQ.4) D=12.0
      IF(K.EQ.5) D=22.0
      DO 40 I=2,NM1
      L=I+1
      J=I-1
      CALL DELTA (X,Y,L,J,D,CX,CY)
      X(K,I)=X(1,I)+CX
   40 Y(K,I)=Y(1,I)+CY
      CALL DELTA (X,Y,2,1,D,CX,CY)
      X(K,1)=X(1,1)+CX
      Y(K,1)=Y(1,1)+CY
      CALL DELTA (X,Y,NPPL,NM1,D,CX,CY)
      X(K,NPPL)=X(1,NPPL)+CX
   50 Y(K,NPPL)=Y(1,NPPL)+CY
      DO 60 K=2,NLINE
      CZ=1.0
      IF(K.EQ.3.OR.K.EQ.4) CZ=0.25
      DO 60 I=1,NPPL
   60 Z(K,I)=Z(1,I)-CZ
      RETURN
      END
```

```
      SUBROUTINE DELTA (A,B,M,L,DI,CX,CY)
C     CALCULATE COORDINATE CHANGES FOR ALL POINTS FROM CENTERLINE
      DIMENSION A(15,90),B(15,90)
      IF(A(9,M)-A(9,L))30,31,30
   31 THETA=1.5708
      GO TO 32
   30 ANGLE=ABS((B(9,M)-B(9,L))/(A(9,M)-A(9,L)))
      THETA=ATAN(ANGLE)
   32 CX=DI*SIN(THETA)
      CY=DI*COS(THETA)
      RETURN
      END
```

```
      SUBROUTINE OFLN2 (X,Y,Z,NPPL)
C     OFFSET SUBROUTINE FOR A TWO LANE ROADWAY
      DIMENSION STA(90),X(15,90),Y(15,90),Z(15,90),DR(90),DL(90)
      DIMENSION BSR(90),BSL(90)
  102 FORMAT(4F10.3)
      NM1=NPPL-1
C     CUT (-)      FILL (+)   FROM CENTERLINE OF ROADWAY
C     DEPTH OF CUT OR FILL ON RIGHT(DR) AND LEFT(DL) SIDE OF ROADWAY
C     BACKSLOPE ON RIGHT(BSR) AND LEFT(BSL) SIDE OF ROADWAY
C   * READ DEPTHS AND BACKSLOPES
      READ (1,102) (DR(I),BSR(I),DL(I),BSL(I),I=1,NPPL)
      WRITE (3,102) DR(NPPL),BSR(NPPL),DL(NPPL),BSL(NPPL)
C     CALCULATIONS
      NLINE=6
      DO 50 K=1,NLINE
      IF(K.EQ.2) D=-22.
      IF(K.EQ.3) D=-12.
      IF(K.EQ.4) D=12.
      IF(K.EQ.5) D=22.
      DO 40 I=2,NM1
      IF(K.EQ.1) D=-22.-ABS(DL(I)*BSL(I))
      IF(K.EQ.6) D=22.+ABS(DR(I)*BSR(I))
      L=I+1
      J=I-1
      CALL DELTA (X,Y,L,J,D,CX,CY)
      X(K,I)=X(9,I)+CX
   40 Y(K,I)=Y(9,I)+CY
      CALL DELTA (X,Y,2,1,D,CX,CY)
      X(K,1)=X(9,1)+CX
      Y(K,1)=Y(9,1)+CY
      CALL DELTA (X,Y,NPPL,NM1,D,CX,CY)
      X(K,NPPL)=X(9,NPPL)+CX
   50 Y(K,NPPL)=Y(9,NPPL)+CY
      DO 60 K=1,NLINE
      DO 60 I=1,NPPL
      IF(K.EQ.1) CZ=DL(I)
      IF(K.EQ.2 .OR.K.EQ.5) CZ=1.0
      IF(K.EQ.3 .OR.K.EQ.4) CZ=.25
      IF(K.EQ.6) CZ=DR(I)
   60 Z(K,I)=Z(9,I)-CZ
      RETURN
      END
```

```
      SUBROUTINE OFLN (X,Y,Z,STA,NP,KEY)
      DIMENSION X(15,300),Y(15,300),Z(15,300),STA(300),STAT(2,100)
      DIMENSION ELEV(2,100),THETA(300)
      NO=NP-1
      IF(KEY.GT.4) GO TO 101
      GO TO (1,101,101,2),KEY
    1 CD=27.
      NCL=7
      GO TO 3
    2 CD=84.
      NCL=13
    3 DO 30 I=1,NO
      IF(X(NCL,I+1)-X(NCL,I)) 20,10,20
   10 THETA(I)=1.5708
      GO TO 30
   20 ANGLE=ABS((Y(NCL,I+1)-Y(NCL,I))/(X(NCL,I+1)-X(NCL,I)))
      THETA(I)=ATAN(ANGLE)
   30 CONTINUE
      THETA(NP)=THETA(NO)
      DO 40 I=2,NO
   40 THETA(I)=(THETA(I-1)+THETA(I))/2.
C   * READ NUMBER OF INFLECTION POINTS FOR RIGHT AND LEFT BACKSLOPES
      READ (1,900) NR,NL
C   * READ STATION AND ELEVATION FOR RIGHT AND LEFT BACKSLOPES
      READ (1,901) (STAT(1,I),ELEV(1,I),I=1,NR)
      READ (1,901) (STAT(2,I),ELEV(2,I),I=1,NL)
      BS=6.
      DO 100 K=1,2
      SIGN=+1.0
      N=6
      IF(KEY.EQ.4) N=12
      NCL=N+1
      NN=NR
      IF(K-1) 55,55,50
   50 NN=NL
      N=1
      SIGN=-1.0
   55 DO 100 I=1,NP
      DO 60 J=2,NN
      IF(STA(I)-STAT(K,J)) 70,80,60
   60 CONTINUE
      WRITE (3,990)
      RETURN
   70 Z(N,I)=ELEV(K,J-1)+(STA(I)-STAT(K,J-1))*(ELEV(K,J)-ELEV(K,J-1))/(S
     1TAT(K,J)-STAT(K,J-1))
      DIST=CD+BS*ABS(Z(N,I)-Z(NCL,I))
      GO TO 90
   80 Z(N,I)=ELEV(K,J)
      DIST=CD
   90 X(N,I)=X(NCL,I)+SIGN*DIST*SIN(THETA(I))
      Y(N,I)=Y(NCL,I)+SIGN*DIST*COS(THETA(I))
  100 CONTINUE
      RETURN
  101 WRITE (3,902) KEY
  902 FORMAT(5H KEY =,I3,10X,39HINVALID VALUE OF KEY IN OFLN SUBROUTINE)
  990 RETURN
  900 FORMAT([illegible])
  901 FORMAT([illegible])
```

```
  940 FORMAT(10X,'ERROR STATEMENT NO. 60  OFLN SUBROUTINE')
      END
```

```
      SUBROUTINE DFOUR (A,B,M,L,DI,CX,CY)
C     CALCULATE COORDINATE CHANGES FOR ALL POINTS FROM CENTERLINE
      DIMENSION A(15,90),B(15,90)
      IF(A(13,M)-A(13,L))30,31,30
   31 THETA=1.5708
      GO TO 32
   30 ANGLE=ABS((B(13,M)-B(13,L))/(A(13,M)-A(13,L)))
      THETA=ATAN(ANGLE)
   32 CX=DI*SIN(THETA)
      CY=DI*COS(THETA)
      RETURN
      END
```

```
      SUBROUTINE OF4L (X,Y,Z,NPPL)
      DIMENSION X(15,90),Y(15,90),Z(15,90)
C     ASSUMES 48 FT MEDIAN, 6 FT INSIDE AND 10 FT OUTSIDE SHOULDERS
      DO 10 I=1,NPPL
      X(13,I)=X(9,I)
      Y(13,I)=Y(9,I)
   10 Z(13,I)=Z(9,I)
      NLINE=11
      SIGN=-1.
      NM1=NPPL-1
      DO 50 K=2,NLINE
      IF(K.GE.7) SIGN=+1.
      D=SIGN*64.
      IF(K.EQ.3.OR.K.EQ.10) D=SIGN*54.
      IF(K.EQ.4.OR.K.EQ.9) D=SIGN*42.
      IF(K.EQ.5.OR.K.EQ.8) D=SIGN*30.
      IF(K.EQ.6.OR.K.EQ.7) D=SIGN*24.
      DO 40 I=2,NM1
      L=I+1
      J=I-1
      CALL DFCUR (X,Y,L,J,D,CX,CY)
      X(K,I)=X(13,I)+CX
   40 Y(K,I)=Y(13,I)+CY
      CALL DFCUR (X,Y,2,1,D,CX,CY)
      X(K,1)=X(13,1)+CX
      Y(K,1)=Y(13,1)+CY
      CALL DFCUR (X,Y,NPPL,NM1,D,CX,CY)
      X(K,NPPL)=X(13,NPPL)+CX
   50 Y(K,NPPL)=Y(13,NPPL)+CY
      DO 60 K=2,NLINE
      CZ=1.44
      IF(K.EQ.3.OR.K.EQ.5.OR.K.EQ.8.OR.K.EQ.10) CZ=.19
      IF(K.EQ.4.OR.K.EQ.9) CZ=0.
      IF(K.EQ.6.OR.K.EQ.7) CZ=.94
      DO 60 I=1,NPPL
   60 Z(K,I)=Z(13,I)-CZ
      RETURN
      END
```

```
      SUBROUTINE CIRCLE (C1,ANGLE,T2,DEFL,PCX,PCY,PTX,PTY,PCS,PTS)
      COMMON/RD1/ DIST,I,N,NDEFL(10),RDEFL(10),DC(10)
      COMMON/CL/X(90),Y(90),STA(100)
  951 FORMAT(////31X,14HCIRCULAR CURVE/)
  952 FORMAT(31X,1HX,16X,1HY,15X,3HSTA/)
  953 FORMAT(16X,2HPC,3F17.2)
  954 FORMAT(16X,2HPT,3F17.2)
  955 FORMAT(//24X,23HDEFLECTION TO THE RIGHT,F7.2,8H DEGREES)
  956 FORMAT(//24X,22HDEFLECTION TO THE LEFT,F7.2,8H DEGREES)
  957 FORMAT(/32X,7HRADIUS=,F10.2)
  958 FORMAT(/30X,17HDEGREE OF CURVE =,F5.2)
  959 FORMAT(/32X,7HLENGTH=,F10.2)
      RAD=5729.58/DC(I)
      CUR=100.*DEFL/DC(I)
      TC=C1
      IF(CUR-TC) 6,8,8
    8 IF(C1) 3,3,1
    1 DA=TC*DC(I)*.000087267
      IF(NDEFL(I))5,5,4
    5 DA=-DA
    4 BNGLE=ANGLE+DA
      X(N)=PCX+TC*SIN(BNGLE)
      Y(N)=PCY+TC*COS(BNGLE)
      STA(N)=PCS+TC
      N=N+1
      IF(CUR-TC)6,3,3
    3 TC=TC+DIST
    2 IF(CUR-TC)6,1,1
    6 T2=TC-CUR
      DA=CUR*DC(I)*.000087267
      IF(NDEFL(I))9,9,10
    9 DA=-DA
   10 ANGLE=ANGLE+DA
      PTX=PCX+SIN(ANGLE)*CUR
      PTY=PCY+COS(ANGLE)*CUR
      PTS=PCS+CUR
C     WRITE CURVE GEOMETRY
      WRITE (3,951)
      WRITE (3,952)
      WRITE (3,953) PCX,PCY,PCS
      WRITE (3,954) PTX,PTY,PTS
      IF(NDEFL(I))23,23,24
   23 WRITE (3,956) DEFL
      GO TO 25
   24 WRITE (3,955) DEFL
   25 WRITE (3,958) DC(I)
      WRITE (3,957) RAD
      WRITE (3,959) CUR
      RETURN
      END
```

```
      SUBROUTINE SPIRAL (S1,ANGLE,T2,SPIR,THES,STX,STY,STS)
      COMMON/RD1/ DIST,I,N,NDEFL(10),RDEFL(10),DC(10)
      COMMON/CL/X(90),Y(90),STA(100)
      DIMENSION SPIR(12)
  952 FORMAT(31X,1HX,16X,1HY,15X,3HSTA/)
  953 FORMAT(16X,2HCS,3F17.2)
  954 FORMAT(16X,2HST,3F17.2)
  955 FORMAT(////28X,20HSPIRAL CURVE (AHEAD)/)
  956 FORMAT(////28X,21HSPIRAL CURVE (BEHIND)/)
  964 FORMAT(16X,2HTS,3F17.2)
  965 FORMAT(//27X,25HLIMITING DEGREE OF CURVE=,F5.2)
  966 FORMAT(/30X,14HSPIRAL LENGTH=,F10.2)
  967 FORMAT(/31X,9HTHETA(S)=,F5.2,8H DEGREES)
  974 FORMAT(16X,2HSC,3F17.2)
      DHES=THES*57.30
      DISTS=100.
      IF(DIST-100.) 26,27,27
   26 DISTS=DIST
C     CALCULATIONS FOR SPIRAL TO CIRCULAR CURVE
   27 IF(S1)1,1,2
    1 TSX=X(N-1)+DIST*SIN(ANGLE)
      TSY=Y(N-1)+DIST*COS(ANGLE)
      TSS=STA(N-1)+DIST
      X(N)=TSX
      Y(N)=TSY
      STA(N)=TSS
      N=N+1
      TS=0.
      GO TO 7
    2 T1=DIST-S1
      TSX=X(N-1)+T1*SIN(ANGLE)
      TSY=Y(N-1)+T1*COS(ANGLE)
      TSS=STA(N-1)+T1
      DA=(S1/SPIR(I))**2*THES/3.
      IF(NDEFL(I))5,5,4
    5 DA=-DA
    4 ANGS=ANGLE+DA
      X(N)=TSX+S1*SIN(ANGS)
      Y(N)=TSY+S1*COS(ANGS)
      STA(N)=TSS+S1
      N=N+1
      TS=S1
    7 IF(SPIR(I)-TS)6,6,3
    3 TS=TS+DISTS
      IF(SPIR(I)-TS)6,6,8
    8 DA=(TS/SPIR(I))**2*THES/3.
      IF(NDEFL(I))11,11,12
   11 DA=-DA
   12 ANGS=ANGLE+DA
      X(N)=TSX+TS*SIN(ANGS)
      Y(N)=TSY+TS*COS(ANGS)
      STA(N)=TSS+TS
      N=N+1
      GO TO 3
    6 C1=TS-SPIR(I)
      DA=THES/3.
      IF(NDEFL(I))9,9,10
    9 DA=-DA
   10 ANGS=ANGLE+DA
      SCX=TSX+SPIR(I)*SIN(ANGS)
```

```
      SCY=TSY+SPIR(I)*COS(ANGS)
      SCS=TSS+SPIR(I)
C     WRITE SPIRAL AHEAD GEOMETRY
      WRITE (3,955)
      WRITE (3,952)
      WRITE (3,964) TSX,TSY,TSS
      WRITE (3,974) SCX,SCY,SCS
      WRITE( 3,965) DC(I)
      WRITE (3,966) SPIR(I)
      WRITE (3,967) DHES
      IF(NDEFL(I))21,21,24
   21 ANGLE=ANGLE-THES
      GO TO 25
   24 ANGLE=ANGLE+THES
C     CDEL IS CENTRAL CURVE DEFLECTION IN DEGREES (ALWAYS POSITIVE)
   25 CDEL=(ABS(RDEFL(I))-2.*THES)*57.30
      ANGLA=ANGLE
      CALL CIRCLE (C1,ANGLA,S1,CDEL,SCX,SCY,CSX,CSY,SCS,CSS)
      CDEL=CDEL*.0174533
      IF(NDEFL(I))19,19,13
   19 CDEL=-CDEL
   13 ANGLE=ANGLE+CDEL
C     CALCULATIONS FOR CIRCULAR CURVE TO TANGENT
      TS=S1
      IF(S1)14,14,15
   14 TS=TS+DISTS
   15 IF(TS-SPIR(I))18,20,20
   18 DA=TS*DC(I)*.000087267-(TS/SPIR(I))**2*THES/3.
      IF(NDEFL(I))16,16,17
   16 DA=-DA
   17 ANGS=ANGLE+DA
      X(N)=CSX+TS*SIN(ANGS)
      Y(N)=CSY+TS*COS(ANGS)
      STA(N)=CSS+TS
      N=N+1
      GO TO 14
   20 T2=TS-SPIR(I)
      DA=2.*THES/3.
      IF(NDEFL(I))22,22,23
   22 DA=-DA
   23 ANGS=ANGLE+DA
      STX=CSX+SPIR(I)*SIN(ANGS)
      STY=CSY+SPIR(I)*COS(ANGS)
      STS=CSS+SPIR(I)
C     WRITE SPIRAL BEHIND GEOMETRY
      WRITE (3,956)
      WRITE (3,952)
      WRITE (3,953) CSX,CSY,CSS
      WRITE (3,954) STX,STY,STS
      WRITE (3,965) DC(I)
      WRITE (3,966) SPIR(I)
      WRITE (3,967) DHES
      RETURN
      END
```

```
      SUBROUTINE VERT (NPVI,NNN,STA,ELEV)
C     ELEVATION SUBROUTINE
C
      DIMENSION STA(100),ELEV(100),XLVC(10),PCSTA(10),PTSTA(10)
C     READ FORMATS
  900 FORMAT(2F10.2)
  901 FORMAT(F10.2)
C
C     WRITE FORMATS
  953 FORMAT(33X,15HBEGINNING POINT/)
  954 FORMAT(31X,9HSTATION =,F11.2/31X,11HELEVATION =,F9.2//)
  955 FORMAT(36X,9HEND POINT/)
  960 FORMAT(36X,5HCURVE,I3//30X,14HCURVE LENGTH =,F9.2/31X,12HPC STATIO
     1N =,F10.2/31X,12HPT STATION =,F10.2//)
      JN=NPVI+2
      NP=NPVI+1
      KK=NNN+1
      KKK=NNN+2+NPVI
C     END POINTS MUST BE BEYOND STATIONED POINTS
C   * READ STATIONS AND ELEVATIONS OF PVI'S INCLUDING END POINTS
      DO 10 K=KK,KKK
   10 READ (1,900) STA(K),ELEV(K)
C     THE END PVI'S ARE ASSIGNED A CURVE LENGTH OF ZERO SO THAT THE FIRS
C        AND THE LAST PVC WILL NOT BE ON THE HORIZONTAL ALIGNMENT
      XLVC(1)=0.
      XLVC(JN)=0.
      IF(NPVI) 30,30,15
C   * ASSIGN LENGTHS OF VERTICAL CURVES AT EACH PVI
   15 DO 20 J=2,NP
   20 READ (1,901) XLVC(J)
C     COMPUTE STATIONS OF PC'S AND PT'S
   30 DO 40 K=KK,KKK
      C2=XLVC(K-NNN)/2.
      PCSTA(K-NNN)=STA(K)-C2
      PTSTA(K-NNN)=STA(K)+C2
   40 CONTINUE
C     WRITE STATION AND ELEVATION OF BEGINNING POINT
      WRITE (3,953)
      WRITE (3,954) STA(KK),ELEV(KK)
      IF(NPVI) 46,46,42
C     WRITE VERTICAL CURVE GEOMETRY
   42 DO 45 I=2,NP
      K=I-1
   45 WRITE (3,960) K,XLVC(I),PCSTA(I),PTSTA(I)
C     WRITE STATION AND ELEVATION OF END POINT
   46 WRITE (3,955)
      WRITE (3,954) STA(KKK),ELEV(KKK)
C     COMPUTE ELEVATIONS AT EACH POINT
      DO 100 I=1,NNN
      DO 60 K=KK,KKK
      IF(PCSTA(K-NNN)-STA(I))50,70,70
   50 IF(PTSTA(K-NNN)-STA(I))60,60,80
   60 CONTINUE
C     POINT ON TANGENT
   70 ELEV(I)=(STA(I)-STA(K-1))*(ELEV(K)-ELEV(K-1))/(STA(K)-STA(K-1))
      ELEV(I)=ELEV(I)+ELEV(K-1)
      GO TO 100
C     POINT ON VERTICAL CURVE
   80 ELEV(I)=(STA(I)-STA(K-1))*(ELEV(K)-ELEV(K-1))/(STA(K)-STA(K-1))
      ELEV(I)=ELEV(I)+ELEV(K-1)
```

```
      G2=(ELEV(K+1)-ELEV(K))/(STA(K+1)-STA(K))
      G1=(ELEV(K)-ELEV(K-1))/(STA(K)-STA(K-1))
      Y=(G2-G1)*(STA(I)-PCSTA(K-NNN))*(STA(I)-PCSTA(K-NNN))
      Y=Y/(XLVC(K-NNN)*2.)
      ELEV(I)=ELEV(I)+Y
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INTERP (A1,AEDGE,A2,B1,B2,C2)
      C2=B1+(B2-B1)*(AEDGE-A1)/(A2-A1)
      RETURN
      END
```

```
      SUBROUTINE DRAW (L,N,H,V,NSKIP)
      DIMENSION NSKIP(18),H(15,300),V(15,300),INPIC(15,300)
C     ISKIP IS TWO TIMES THE INTERVAL NUMBER FOR CROSS LINES
      LSAVE=L
      ISKIP=NSKIP(17)*2
      WRITE (3,505)
  505 FORMAT(7(/),16H DRAW SUBROUTINE)
      HMAX=10.0
      HMIN=-10.0
      VMAX=5.0
      VMIN=-5.0
C     PROGRAM DRAWS LINES BACK AND FORTH
      DO 100 I=1,L,2
      IH1=0
      IV1=0
      NFRST=0
      IHV3=0
      NN=NSKIP(I)
      IF(NN.EQ.0) GO TO 46
      DO 7 K=1,NN
    7 INPIC(I,K)=1
   46 NN=NN+1
C     DRAWS LINES 1,3,5,7 FROM 1 TO N
      DO 98 J=NN,N
C     NEXT POINT H2, V2
      H2=H(I,J)
      V2=V(I,J)
      INPIC(I,J)=0
      IH2=0
C     HMIN CHECK
      IF(H2-HMIN)1,2,2
    1 IH2=1
      INPIC(I,J)=1
      IF(NFRST)2,18,2
    2 IF(IH1-1)3,3,4
    3 IF(IH2-IH1)5,4,6
    5 CALL INTERP(H1,HMIN,H2,V1,V2,V1)
      H1=HMIN
      IF(V1-VMIN)31,9,8
    8 IF(VMAX-V1)47,9,9
   31 IV1=1
      GO TO 10
   47 IV1=2
      GO TO 10
    9 IV1=0
   10 IP1=1
      GO TO 18
    6 H3=H2
      V3=V2
      IHV3=1
      CALL INTERP(H1,HMIN,H2,V1,V2,V2)
      H2=HMIN
      IH3=IH2
      IH2=0
      GO TO 18
C     HMAX CHECK
    4 IF(HMAX-H2)11,12,12
   11 IH2=2
      INPIC(I,J)=1
      IF(NFRST)12,18,12
```

```
   12 IF(IH2-IH1)13,18,14
   13 CALL INTERP(H1,HMAX,H2,V1,V2,V1)
      H1=HMAX
      IF(V1-VMIN)48,17,15
   15 IF(VMAX-V1)49,17,17
   48 IV1=1
      GO TO 16
   49 IV1=2
      GO TO 16
   17 IV1=0
   16 IP1=1
      GO TO 18
   14 H3=H2
      V3=V2
      IHV3=1
      CALL INTERP(H1,HMAX,H2,V1,V2,V2)
      H2=HMAX
      IH3=IH2
      IH2=0
   18 IV2=0
C     VMIN CHECK
      IF(V2-VMIN)19,20,20
   19 IV2=1
      INPIC(I,J)=1
      IF(NFRST)20,37,20
   20 IF(IV1-1)21,21,22
   21 IF(IV2-IV1)41,22,42
   41 IF(IH2)37,23,37
   23 CALL INTERP(V1,VMIN,V2,H1,H2,H1)
      V1=VMIN
      IP1=1
      GO TO 32
   42 IF(IH2)37,24,37
   24 H3=H2
      V3=V2
      IHV3=1
      IH3=IH2
      CALL INTERP(V1,VMIN,V2,H1,H2,H2)
      V2=VMIN
      GO TO 32
C     VMAX CHECK
   22 IF(VMAX-V2)25,26,26
   25 IV2=2
      INPIC(I,J)=1
      IF(NFRST)26,37,26
   26 IF(IV2-IV1)43,29,44
   43 IF(IH2)37,27,37
   27 CALL INTERP(V1,VMAX,V2,H1,H2,H1)
      V1=VMAX
      IP1=1
      GO TO 32
   44 IF(IH2)37,28,37
   28 H3=H2
      V3=V2
      IHV3=1
      IH3=IH2
      CALL INTERP(V1,VMAX,V2,H1,H2,H2)
      V2=VMAX
      GO TO 32
   29 IF(IH2)37,30,37
```

```
   30 IF(IV2)37,32,37
C     ORIGINAL POINT OUT OF PICTURE
   32 IF(NFRST)34,33,34
   33 CALL PLOT(-V2,+H2,3)
      GO TO 37
   34 IF(IP1)36,36,35
   35 CALL PLOT(-V1,+H1,3)
   36 CALL PLOT(-V2,+H2,2)
   37 IF(IHV3)38,38,39
   38 H1=H2
      V1=V2
      GO TO 40
   39 H1=H3
      V1=V3
      IH2=IH3
   40 NFRST=1
      IH1=IH2
      IV1=IV2
      IHV3=0
      IP1=0
   98 CONTINUE
C     DRAWS LINES 2,4,6,8 FROM N TO 1
      NFRST=0
      II=I+1
      IF(II.GT.L) GO TO 100
      IH1=0
      IV1=0
      NN=NSKIP(I+1)
      J=N+1
      IF(NN.EQ.0) GO TO 97
      DO 197 K=1,NN
  197 INPIC(I+1,K)=1
   97 NN=NN+1
      DO 99 K=NN,N
      J=J-1
C     NEXT POINT H2, V2
      H2=H(I+1,J)
      V2=V(I+1,J)
      INPIC(I+1,J)=0
      IH2=0
C     HMIN CHECK
      IF(H2-HMIN)51,52,52
   51 IH2=1
      INPIC(I+1,J)=1
      IF(NFRST)52,68,52
   52 IF(IH1-1)53,53,54
   53 IF(IH2-IH1)55,54,56
   55 CALL INTERP(H1,HMIN,H2,V1,V2,V1)
      H1=HMIN
      IF(V1-VMIN)50,59,58
   58 IF(VMAX-V1)81,59,59
   50 IV1=1
      GO TO 60
   81 IV1=2
      GO TO 60
   59 IV1=0
   60 IP1=1
      GO TO 68
   56 H3=H2
      V3=V2
```

```
      IHV3=1
      CALL INTERP(H1,HMIN,H2,V1,V2,V2)
      H2=HMIN
      IH3=IH2
      IH2=0
      GO TO 68
C     HMAX CHECK
   54 IF(HMAX-H2)61,62,62
   61 IH2=2
      INPIC(I+1,J)=1
      IF(NFRST)62,68,62
   62 IF(IH2-IH1)63,68,64
   63 CALL INTERP(H1,HMAX,H2,V1,V2,V1)
      H1=HMAX
      IF(V1-VMIN)96,67,65
   65 IF(VMAX-V1)118,67,67
   96 IV1=1
      GO TO 66
  118 IV1=2
      GO TO 66
   67 IV1=0
   66 IP1=1
      GO TO 68
   64 H3=H2
      V3=V2
      IHV3=1
      CALL INTERP(H1,HMAX,H2,V1,V2,V2)
      H2=HMAX
      IH3=IH2
      IH2=0
   68 IV2=0
C     VMIN CHECK
      IF(V2-VMIN)69,70,70
   69 IV2=1
      INPIC(I+1,J)=1
      IF(NFRST)70,87,70
   70 IF(IV1-1)71,71,72
   71 IF(IV2-IV1)91,72,92
   91 IF(IH2)87,73,87
   73 CALL INTERP(V1,VMIN,V2,H1,H2,H1)
      V1=VMIN
      IP1=1
      GO TO 82
   92 IF(IH2)87,74,87
   74 H3=H2
      V3=V2
      IHV3=1
      IH3=IH2
      CALL INTERP(V1,VMIN,V2,H1,H2,H2)
      V2=VMIN
      GO TO 82
C     VMAX CHECK
   72 IF(VMAX-V2)75,76,76
   75 IV2=2
      INPIC(I+1,J)=1
      IF(NFRST)76,87,76
   76 IF(IV2-IV1)93,79,94
   93 IF(IH2)87,77,87
   77 CALL INTERP(V1,VMAX,V2,H1,H2,H1)
      V1=VMAX
```

```
      IP1=1
      GO TO 82
   94 IF(IH2)87,78,87
   78 H3=H2
      V3=V2
      IHV3=1
      IH3=IH2
      CALL INTERP(V1,VMAX,V2,H1,H2,H2)
      V2=VMAX
      GO TO 82
   79 IF(IH2)87,80,87
   80 IF(IV2)87,82,87
C     ORIGINAL POINT OUT OF PICTURE
   82 IF(NFRST)84,83,84
   83 CALL PLOT(-V2,+H2,3)
      GO TO 87
   84 IF(IP1)86,86,85
   85 CALL PLOT(-V1,+H1,3)
   86 CALL PLOT(-V2,+H2,2)
   87 IF(IHV3)88,88,89
   88 H1=H2
      V1=V2
      GO TO 90
   89 H1=H3
      V1=V3
      IH2=IH3
   90 NFRST=1
      IH1=IH2
      IV1=IV2
      IHV3=0
      IP1=0
   99 CONTINUE
  100 CONTINUE
      IF(NSKIP(18)) 147,147,148
  148 WRITE(3,501)
  501 FORMAT(1H1,6(13H  I   J   INPIC,8X)//)
      WRITE (3,502) ((I,J,INPIC(I,J),J=1,N),I=1,L)
  502 FORMAT(6(1X,2I3,I5,9X))
C
  147 IF(NSKIP(16)) 140,140,142
  140 L=4
      DO 141 J=1,3
      GO TO (143,144,145),J
  143 JJ=1
      KK=2
      GO TO 146
  144 JJ=3
      KK=1
      GO TO 146
  145 JJ=2
      KK=3
  146 NN=NSKIP(JJ)+1
      DO 141 I=NN,N
      INPIC(KK,I)=INPIC(JJ,I)
      H(KK,I)=H(JJ,I)
  141 V(KK,I)=V(JJ,I)
      NSKIP(2)=NSKIP(1)
      NSKIP(1)=NSKIP(3)
      NSKIP(3)=NSKIP(2)
C     DRAWS CROSS LINES AT EVERY STATION BACK AND FORTH
```

```
      C    DETERMINES MINIMUM NSKIP
      142 WRITE (3,504)
      504 FORMAT(7(/),12H CROSS LINES)
          MSKIP=NSKIP(1)
          DO 101 K=2,L
          IF(NSKIP(K)-MSKIP)102,101,101
      102 MSKIP=NSKIP(K)
      101 CONTINUE
          MSKIP=MSKIP+1
          IF(NSKIP(16)-4) 302,300,302
      300 L=14
          DO 301 I=1,N
          H(14,I)=H(12,I)
          V(14,I)=V(12,I)
          H(13,I)=H(11,I)
          V(13,I)=V(11,I)
          H(12,I)=H(10,I)
          V(12,I)=V(10,I)
          H(11,I)=H(9,I)
          V(11,I)=V(9,I)
          H(10,I)=H(9,I)
          V(10,I)=V(9,I)
          H(9,I)=H(8,I)
          V(9,I)=V(8,I)
          H(8,I)=H(7,I)
          V(8,I)=V(7,I)
          H(7,I)=H(6,I)
          V(7,I)=V(6,I)
          H(6,I)=H(5,I)
          V(6,I)=V(5,I)
          H(5,I)=H(4,I)
          V(5,I)=V(4,I)
          INPIC(14,I)=INPIC(12,I)
          INPIC(13,I)=INPIC(11,I)
          INPIC(12,I)=INPIC(10,I)
          INPIC(11,I)=INPIC(9,I)
          INPIC(10,I)=INPIC(9,I)
          INPIC(9,I)=INPIC(8,I)
          INPIC(8,I)=INPIC(7,I)
          INPIC(7,I)=INPIC(6,I)
          INPIC(6,I)=INPIC(5,I)
      301 INPIC(5,I)=INPIC(4,I)
      C    STARTS CROSS LINES AT BOTTOM OF PICTURE, PROGRESSES TO TOP
      302 DO 200 JJ=MSKIP,N,ISKIP
          J=JJ
          NFRST=0
          ID=1
          I=L+1
      C    DRAWS MSKIP, MSKIP+2,ETC, LINES RIGHT TO LEFT
          DO 198 K=1,L,2
          I=I-1
          IF(NFRST)104,103,104
      103 IF(INPIC(I,J))106,105,106
      105 SAVEV=-V(I,J)
          SAVEH=H(I,J)
          KH=I
          KV=J
          ID=0
      106 NFRST=1
          GO TO 112
```

```
  104 IF(ID)107,108,107
  107 IF(INPIC(I,J))112,109,112
  109 SAVEV=-V(I,J)
      SAVEH=H(I,J)
      KH=I
      KV=J
      ID=0
      GO TO 112
  108 IF(INPIC(I,J))110,111,110
  110 ID=1
      GO TO 112
  111 CALL PLOT (SAVEV,SAVEH,3)
      CALL PLOT(-V(I,J),+H(I,J),2)
  112 I=I-1
      IF(ID)198,114,198
  114 IF(INPIC(I,J))117,116,117
  116 CALL PLOT (SAVEV,SAVEH,3)
      CALL PLOT(-V(I,J),+H(I,J),2)
  117 ID=1
  198 CONTINUE
      J=JJ+NSKIP(17)
      IF(J.GT.N) GO TO 200
      NFRST=0
      ID=1
      I=0
C     DRAWS MSKIP+1, MSKIP+3, ETC, LINES LEFT TO RIGHT
      DO 199 K=1,L,2
      I=I+1
      IF(NFRST)154,153,154
  153 IF(INPIC(I,J))156,155,156
  155 SAVEV=-V(I,J)
      SAVEH=H(I,J)
      KH=I
      KV=J
      ID=0
  156 NFRST=1
      GO TO 162
  154 IF(ID)157,158,157
  157 IF(INPIC(I,J))162,159,162
  159 SAVEV=-V(I,J)
      SAVEH=H(I,J)
      KH=I
      KV=J
      ID=0
      GO TO 162
  158 IF(INPIC(I,J))160,161,160
  160 ID=1
      GO TO 162
  161 CALL PLOT (SAVEV,SAVEH,3)
      CALL PLOT(-V(I,J),+H(I,J),2)
  162 I=I+1
      IF(ID)199,164,199
  164 IF(INPIC(I,J))167,166,167
  166 CALL PLOT (SAVEV,SAVEH,3)
      CALL PLOT(-V(I,J),+H(I,J),2)
  167 ID=1
  199 CONTINUE
  200 CONTINUE
      L=LSAVE
      WRITE (3,506) MSKIP
```

```
  506 FORMAT(//6X,'FIRST POINT ***',I5)
      RETURN
      END
```

A STUDY OF SPIRAL TRANSITION CURVES AS RELATED TO THE VISUAL QUALITY OF HIGHWAY ALIGNMENT

by

JERRY SHELDON MURPHY

B. S., Kansas State University, 1968

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

The purpose of this study was to investigate the importance of the spiral curve in the visual appearance of a horizontal curve. This was to be accomplished by simulating actual and theoretical conditions of roadway geometry and rating the visual appearance of each location. The simulation involved converting three-dimensional coordinates into two dimensional perspective coordinates and plotting these coordinates thus giving a perspective drawing of the roadway.

Many different combinations of sight distance, display angle and roadway geometry were simulated and rated in an attempt to determine the factors which affect the visual appearance of a roadway. It was found that increasing sight distance caused the appearance of a curve to become less acceptable. The display angle was found to be proportional to the appearance of the curve, i.e. an increase in the display angle resulted in an improved visual appearance of the curve. The geometry of the curve, spiral length, likewise affected the visual acceptability of the curve. The longer the length of spiral used, the more visually acceptable it became.

A preliminary investigation was undertaken to determine the feasibility of using the rate of change of slope of a curve in the perspective picture plane as a means of determining the visual appearance of a curve without drawing a perspective view. This investigation indicated that this approach does warrant further study.