## APPENDIX E

TEMPLATE PROCESSES

ROADWAY TEMPLATE SHAPES

Roadway template data is used to define the shape of the roadway surface at desired points along the horizontal alignment. IGrds interpolates the shape of the roadway between the points specified by the designer. Superelevation and widening data are discussed in Appendices F and G, respectively, and supplement template data.

The definition of the shape includes locating the template point that is at the center of the roadway and the template point which is precisely on the vertical alignment. Horizontal alignment, vertical alignment, and template data are thus combined to create a continuous roadway surface. Shapes are stored and recalled by number.

The roadway template shape at a given point is described by the designer by giving a series of slopes and distances. These slopes and distances are referred to as roadway template segments. A typical template is shown below. The template points and segments are numbered from left to right (i.e., points 1 - 6, segments 1 - 5), as shown below:
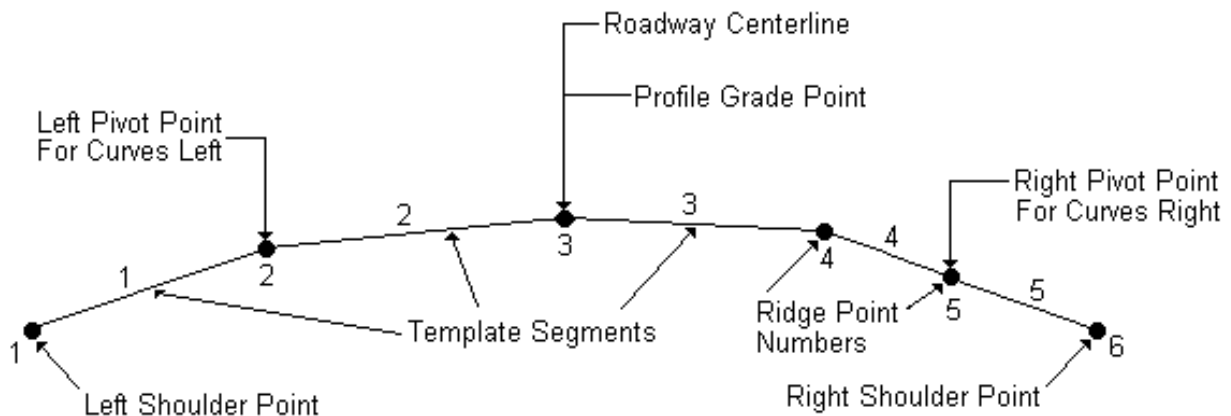
Template Types

Templates may be defined as either Subgrade (S) or Finished (F), and a surface depth may be specified for Finished. An additional elevation correction may be stored with the vertical alignment. These specifications are used for computing elevations for earthwork as shown here:
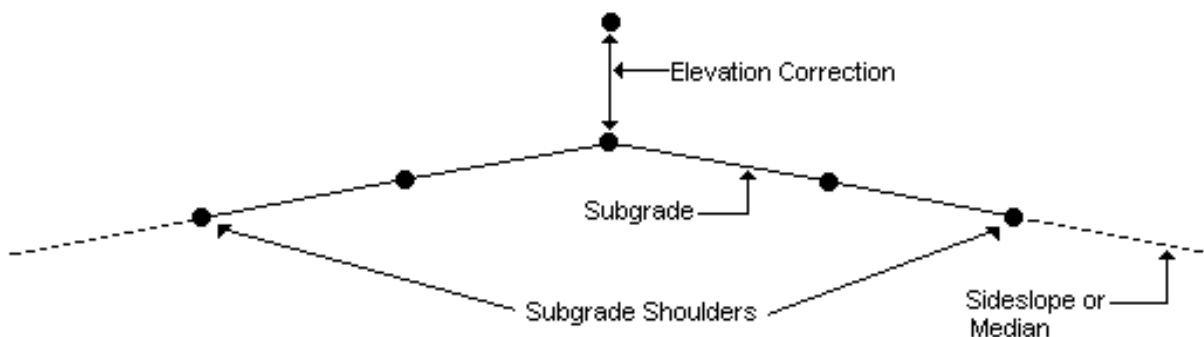
S/F   Template Subgrade Elevation Computation*

	Template		Profile		Profile Grade**	
S	Subgrade	=	Grade	+	Elevation	
	Elevation		Elevation		Correction	

	Template		Profile		Template		Profile**
F	Subgrade	=	Grade	-	Surface	+	Elevation
	Elevation		Elevation		Depth		Correction

     *   The arithmetic operations indicated are performed algebraically, taking into account the signs of the values.

     **   See Appendix D for a discussion of the application of elevation correction.

For subgrade templates, IGrds assumes that the difference between the profile grade elevation and the template subgrade elevation has been specified by the elevation correction value entered or is zero. Finished grades may be computed in horizontal alignment geometry calculations by indicating an elevation correction.

For finished grade templates, both the template surface depth and profile grade elevation correction specifications are applied. For finished grade templates, the subgrade shoulder points will be computed by extending some template segments (at subgrade elevation) until they intersect the median or sideslope, as specified by the various segment slope options. If no intersection results, then the extension will end at the beginning horizontal limits of the finished grade ditch and a vertical connection will be made at that point.

In this case, the template may be used directly in horizontal alignment geometry computations. A surface depth is used to indicate the subgrade shape. The surface depth given is applied ONLY in design and earthwork computations. Other uses of the template described WILL NOT reflect this depth. Generally, for non-superelevated conditions, the design earthwork process defines a subgrade surface parallel to the finished grade template, and extends the leftmost and rightmost segments to intersect the sideslope or median that was built from the finished grade shoulder. These intersections become the subgrade shoulder points.

However, for non-superelevated conditions, if the subgrade is desired to be parallel to the travel lanes, but not to the shoulders, as shown below, then a "F" should be specified for the left and right segments defining the travel lanes (one on each side of the centerline). See Figure E-1 below. For superelevated conditions, the finish grade and subgrade segment options independently control segment slopes. See the discussion later in this Appendix.
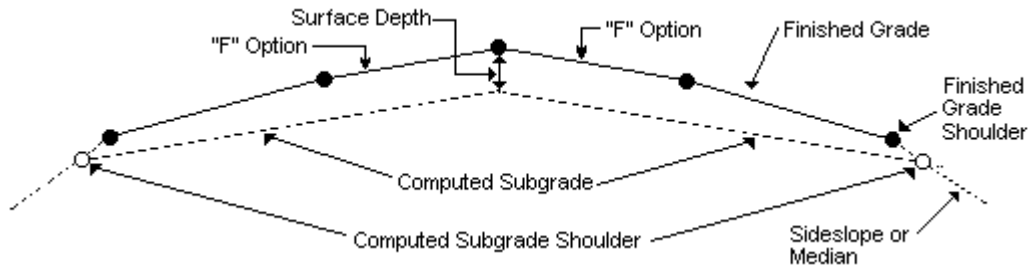

Figure E-1 - Illustration of Resulting Subgrade Using Template Slope Option F

If, for non-superelevated conditions, the subgrade is to be parallel to all of the finished grade template segments, as shown below, then the left and right travel lane segment slope options must be blank. See Figure E-2 below. Again, for superelevated conditions, the finish grade and subgrade segment options independently control segment slopes.
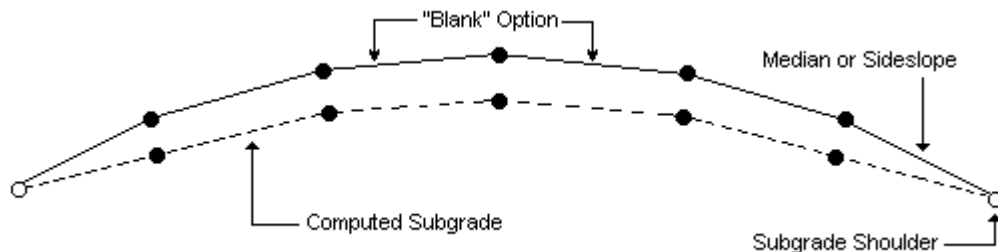

Figure E-2 - Illustration of Resulting Subgrade Using Template Slope Option Blank

Some design conditions require the use of the subgrade crossover capability. See the section entitled Off Template Control for a discussion of this capability. Likewise, some design conditions require the use of "trenched" subgrade sections. See the section entitled Trenched Subgrade, later in this Appendix, for a discussion of this alternative.

Template Segments

Each template may consist of from 1 to 98 template segments (2 to 99 points). The points at the beginning and end of each segment are called ridge points. Ridge points and segments are numbered consecutively from left to right. The first and last ridge points are the shoulder points. To tie the template to other design features, there must be ridge points at the:

°   point coinciding with the horizontal alignment (centerline point)

°   point coinciding with the vertical alignment (profile grade point) (may be coincident with the centerline point; however, this is not mandatory)

°   point about which curves to the left are superelevated (left pivot point)

°   point about which curves to the right are superelevated (right pivot point)

See the section entitled Off Template Control, later in this Appendix, for a discussion of an alternate method for defining the key ridge line points.

Segment slopes and distances are defined as shown here:
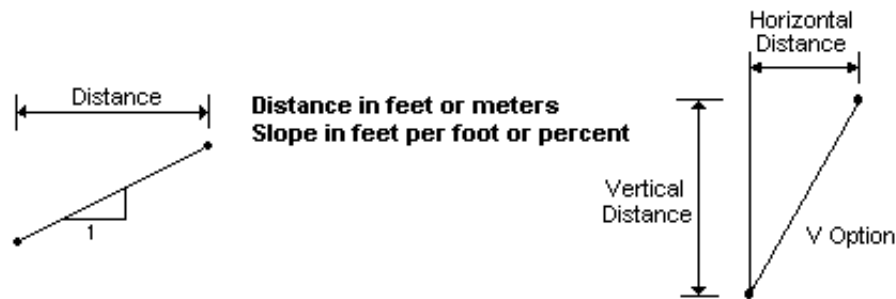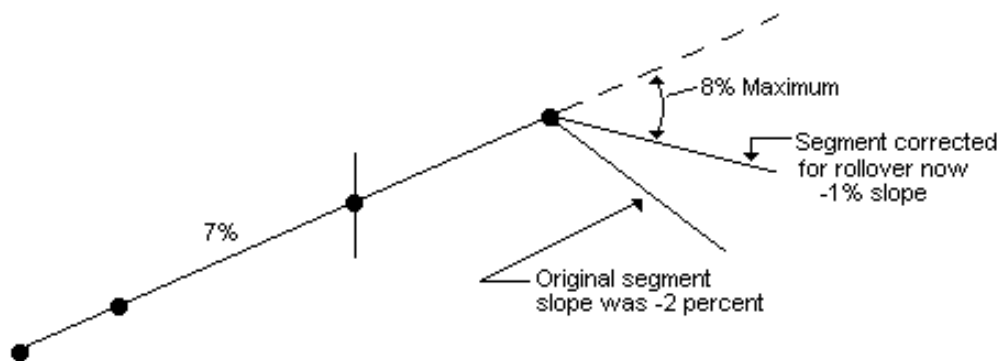

Slope Segment Options

Slope segment options control how segments behave in superelevated conditions. Slope segment options can be specified for both finish grade and subgrade segments. The slope options for finished grade, and/or subgrade template segments are summarized below:

°   Blank - Normal superelevation applied to the segment.

°   F -   Subgrade segments are parallel to this controlling segment. (See earlier discussion. The F option is only used with finished grade templates). Normal superelevation applied to the segment.

°   H -   No superelevation applied to the segment.

°   V -   Vertical distance, no superelevation applied to the segment.

°   R -   On the high side, no superelevation applied to the segment, a rollover check is performed. On the low side, normal superelevation applied to the segment. See the R segment option discussion.

°   L -   On the high side, segment is limited to a specific cross slope. On the low side, normal superelevation applied to the segment. See the L segment option discussion.

°   M -   On the high side, segment superelevates normally. On the low side, the segment is limited to a specific cross slope. See the M segment option discussion.

°   U -   User defined option. Segment option varies depending on superelevation rate for the curve. See the U segment option discussion.

°   T -   One-half normal superelevation applied to the segment, truck lane.
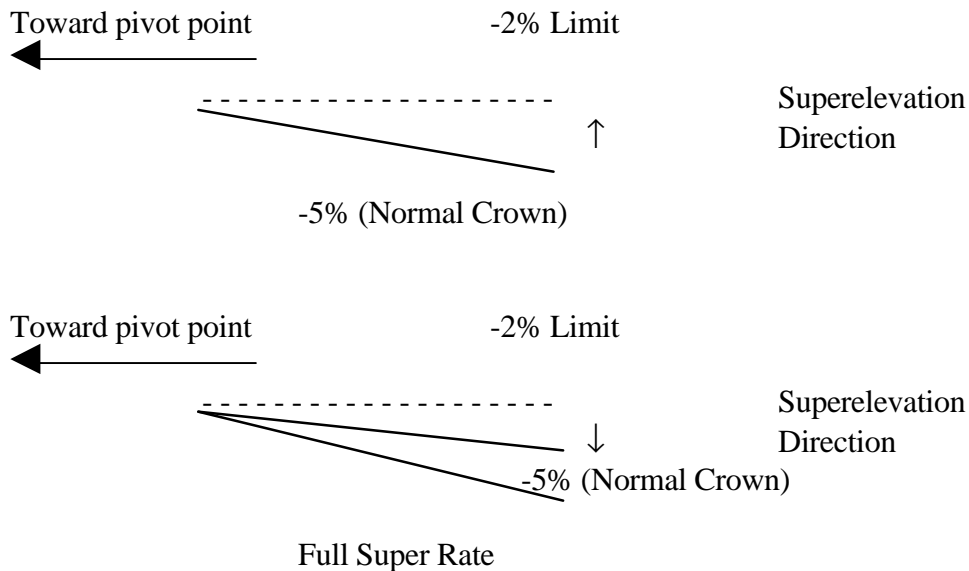
<u>R Segment Option</u>

On the high side of superelevated curves, the difference between adjacent template segment slopes can be controlled using the R segment slope option. The R segment slope option checks the R segment slope with the adjacent segment slope and limits the algebraic difference in slopes to a specified maximum (default 0.08), as shown below. This specified maximum algebraic difference in slopes may be changed by the designer for individual segments. The segment checked will be the adjacent segment from the R coded segment in the direction of the pivot point. If the checked segment has a vertical (V) segment slope option, then the program will look for the first non-vertical coded segment in the same direction. Two R segments can be coded for each side of the template. Within the IGrds/IG Option, the user can change the rollover rate as part of the template shape definition. The segment superelevates normally on the low side of superelevated curves.
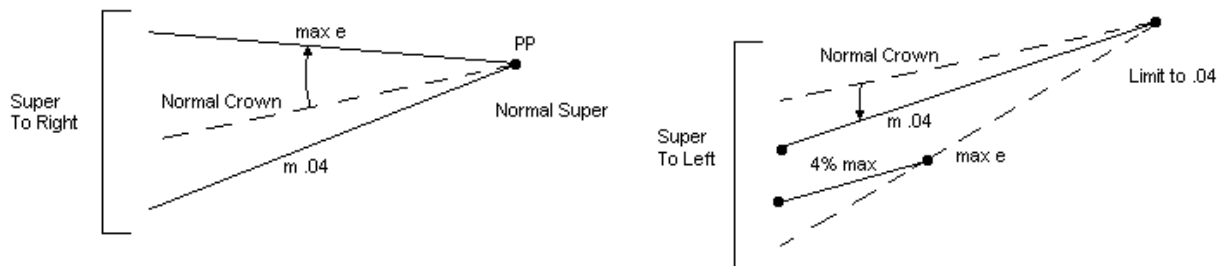
L Segment Option

When superelevating, the L segment option implies that the segment is limited to a specific cross slope. It can be used, for example, to achieve a "broken back" subgrade line so that moisture will not intrude into the pavement structure. In the sketch shown below, the normal crown for the segment is -5%, and the limit is set to -2%. The limiting slope will be retrieved from the secondary option data element, in the same fashion as the R option. The segment will superelevate up to -2%, then be held at that value. If superelevating the other direction (e.g., clockwise in this example), the segment will superelevate normally since the superelevated slope is always less than the limit slope.

Toward pivot point   -2% Limit

Superelevation
Direction

-5% (Normal Crown)

Toward pivot point   -2% Limit

Superelevation
Direction

-5% (Normal Crown)

Full Super Rate

M Segment Option

The M option is actually the reverse of the L option. It implies that on the lowside of superelevation, the segment will be limited to a specific slope and will superelevate normally on the high side. For example, if the segment option is M .04, then it will be limited to .04 when superelevating to the left and will superelevate normally when superelevating to the right.

U Segment Option

The U (user defined) option is a very powerful segment option. The user agency or designer establishes rules that affect how a segment behaves in superelevation situations. These rules are stored in the design criteria table (ha.tbl) and referred to using the U segment options. An unlimited number of U segment options can be defined. A new process interprets U segment options and retrieves the appropriate IGrds segment option. When a U segment option is encountered, the process retrieves the appropriate logic data elements. These values are plugged into the logic equation for processing. The logic equation is in terms of the signed superelevation rate (e) for the curve being processed, and is shown below.

(Line 1) **If e** *greater than* value_1*and less than or equal to* value_2   **Then** *segment_option seg._sec._op.*
(Line 2) **Else If e** *greater than* value_1 *and less than or equal to* value_2 **Then** *segment_option seg._sec._op.*
(Line 3) **Else If e** *greater than* value_1 *and less than or equal to* value_2 **Then** *segment_option seg._sec._op.*

For example, if the values for a particular user defined segment option are as shown below in the ASCII table and as illustrated in the sketch below:

```
Begin Block Option 2 Finish Grade Right Shoulder
  -99            .03        R          .04
  .03            .05        L         -.01
  .05            99
End Block
```
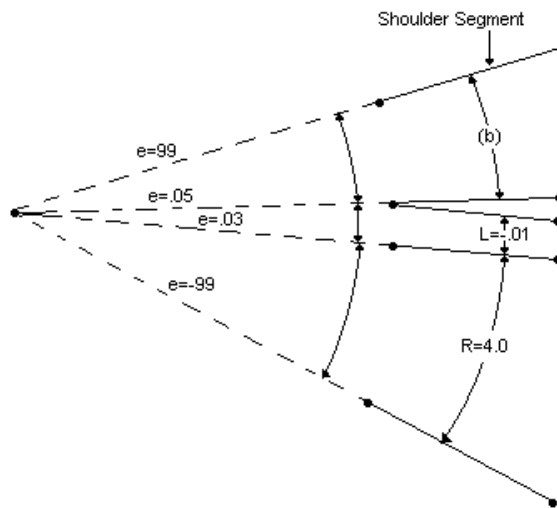

then the logic equation would appear thusly:

```
        If e GT -99 AND LE .03 Then seg opt = R, sec. Seg.opt = .04
    Else  If e GT .03 AND LE .05 Then seg opt = L, sec. Seg.opt = -.01
    Else If e GT .05 AND LE 99 Then seg opt = blank, sec opt = blank
```

Interpreting the logic table: If e is .043, then the segment option would be L and the limiting slope would be -.01. If the logic table fails for any reason, then the segment option is set to blank and a message is put in the error log.

Subgrade Segment Option Processing Rules

Generally, there is always a "one for one" relationship between surface and subgrade segments, including vertical finish grade segments. However, vertical choker and subgrade steps can exist on the subgrade without a corresponding finished grade segment. In essence, these vertical subgrade steps do not count as a segment and do not have segment options.

For normal crown conditions on subgrade segments, the following rules apply:

°   If there is an F (follow segment) associated with a finish grade segment on this side of the centerline, then all subgrade segments are at the same slope as the controlling segment. "Step" segments are vertical and do not count.

°   If the subgrade cross over toggle is set and there is an F associated with a finished grade segment on the other side of the centerline, the same rule applies.

°   If there is no F associated with a finish grade segment on this side of the centerline and the subgrade cross over toggle is not set, then all subgrade segments are at the same slope as the finish grade segment above the subgrade segment. Again, step segments are vertical and do not count.

For superelevated conditions on subgrade segments, the subgrade segment options control how the subgrade segments react, independently of finish grade segment options. See the sketches below for examples of superelevated sections.

Secondary Keypoints

In addition to the centerline, profile grade, and pivot points, the user can define which points within the template represent the edge of travel, the back of curbs, and the gutter points. These points are identified in the Earthwork Design Cross Section and Slope Stake Reports. They can also be identified within the cross section plotting process. The ridgelines which correspond to the keypoints can be drawn in the plan view as well as the profile view.
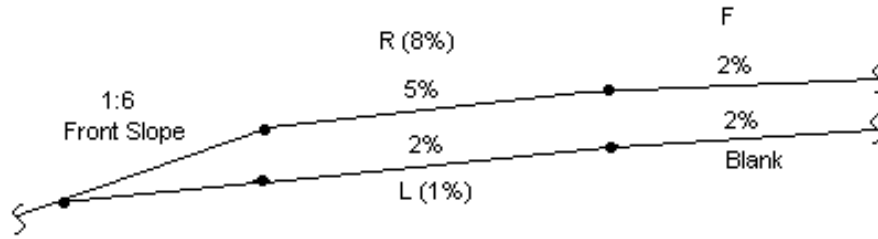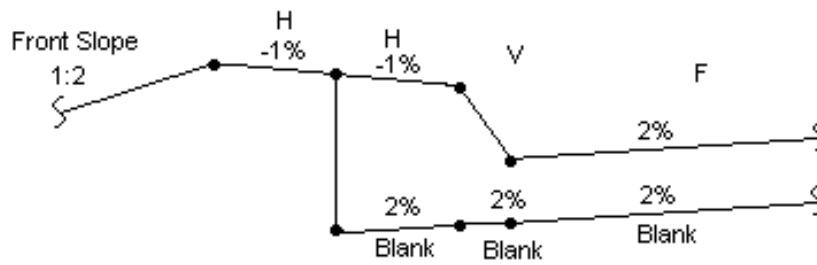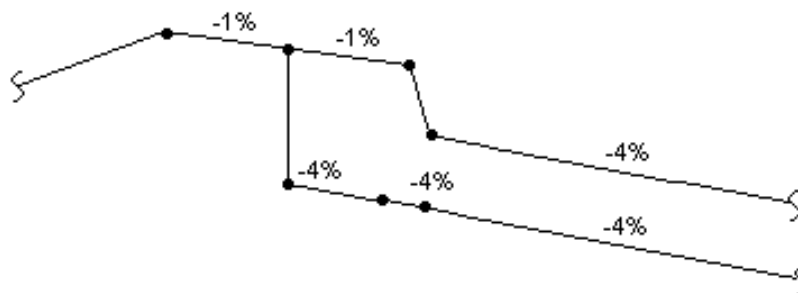
Normal Crown
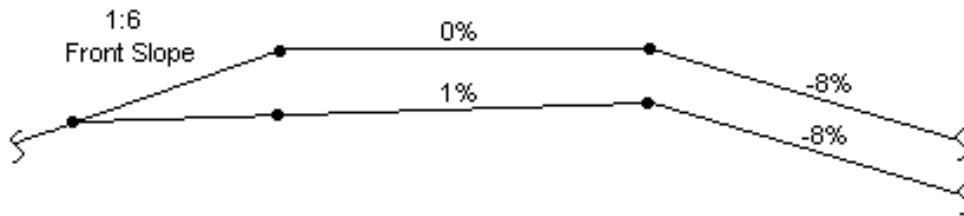
Superelevated (Curve to Right)

Typical Rural Conditions


Normal Crown

Superelevated (Curve to Right)

Typical Urban Section (Type D Trench Section)

Off Template Control

When using the off template control option, vertical control points to be constructed may lie off the template. Template design process accepts profile grade points and superelevation pivot points that will not be located within the final template configuration. When using off template control, the centerline point, profile grade point, and the left and right pivot points must all be the same point. Examples of designs where off template planes are not included in the final template follow.
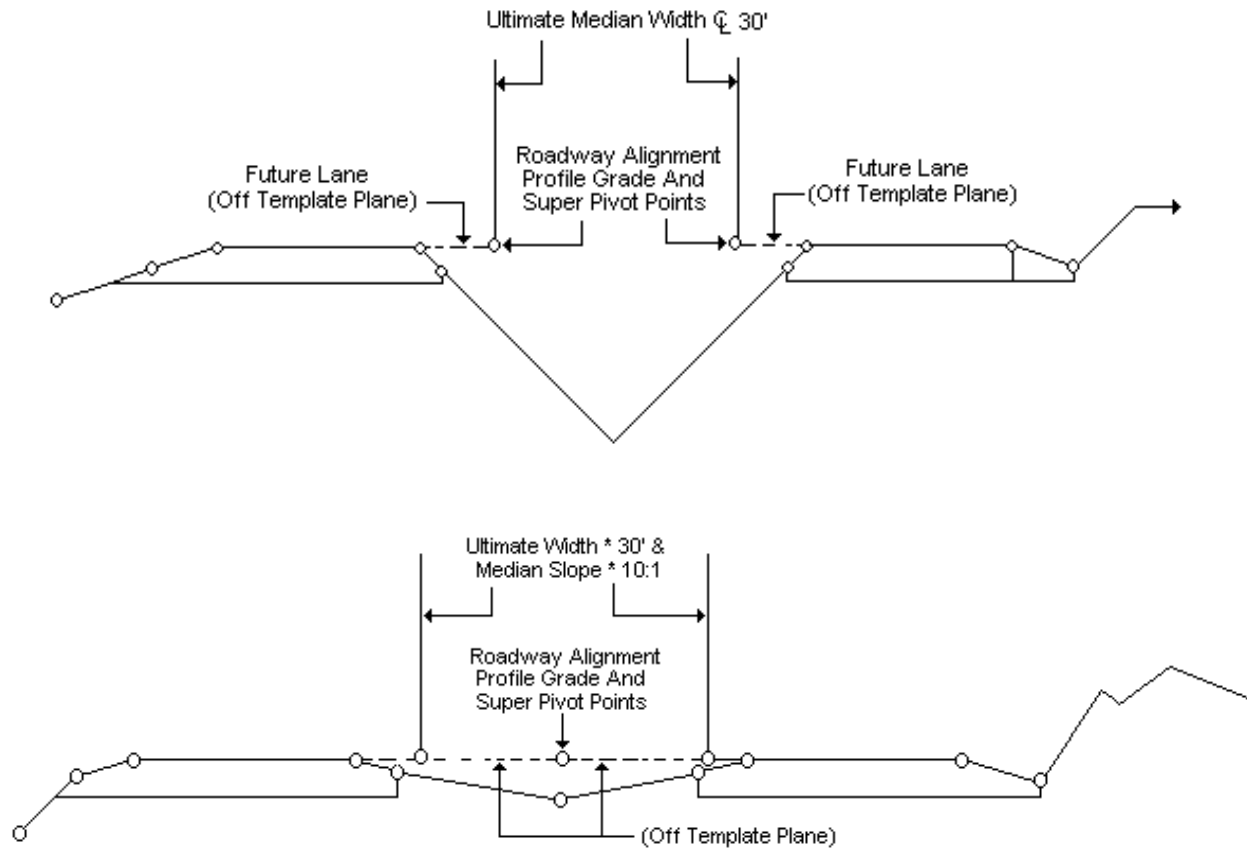
The off template control option makes it easier to maintain the subgrade plane parallel to one controlling finished grade segment. The following illustration is an example.
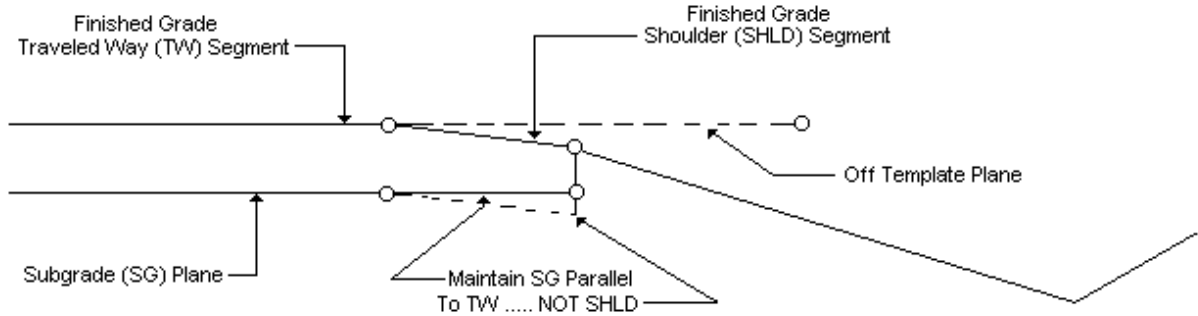
The off template control option is only applicable to finished grade templates.

When using the off template control option, template data specified from left to right, including the off template data (i.e., future lane, median shoulder, etc.) needs to be entered. The off template point (i.e., centerline point, profile grade point, left and right pivot point) must be a ridge point. This data activates the option.

Template data is specified as if the "dummy segment" was to be part of the final configuration. The "dummy segment" must be next to the segment that will be kept when the "dummy" is dropped during the final calculation of the template.
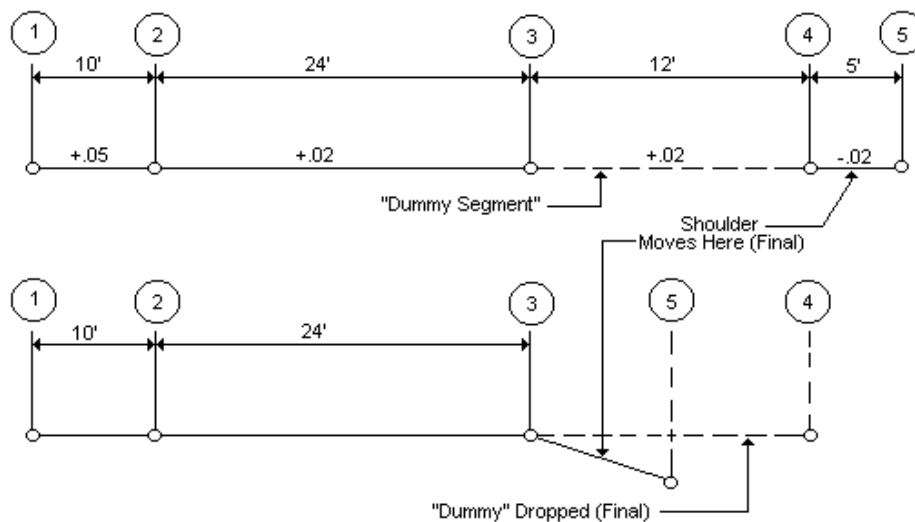
The number of the new rotational point, the on template point, must be identified. The new point must be a ridge point, a point included on the final template and a point that is contiguous to the dummy segment. This point on the design cross section list will be identified as the centerline point.

Entry of the on template point will activate the off template control option.
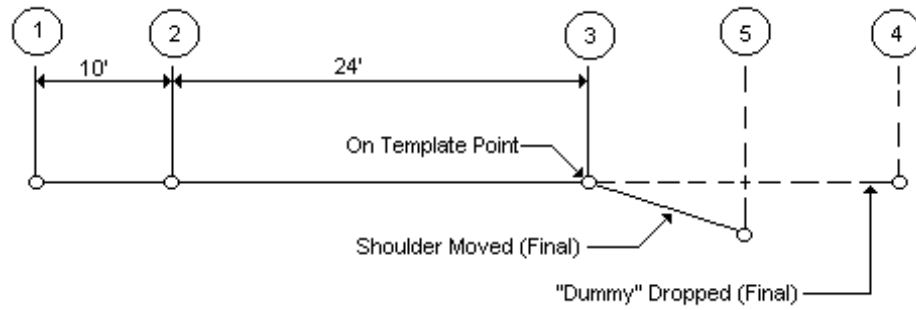
Note: Theoretically, the on template point becomes the centerline, profile grade and pivot for superelevation rotation.

Using the segment slope option F results in the coded segment controlling the cross slope of the subgrade plane. The F slope option requires that a minimum of two segment templates be described. The F option may be used to control the subgrade plane on one or both sides of the centerline.

Since the template on the median side of the centerline may contain only one segment and/or not have a segment with the controlling cross slope, it is necessary to control the subgrade plane when the need arises; hence, the subgrade cross over option. When using the subgrade cross over option, only one F segment slope option is allowed per template description. Using more than one F slope option may cause the system to terminate processing abnormally or make erroneous calculations. If the subgrade plane is to be parallel for the entire template, left and right of the on template point, the F option is specified for the finished grade segment that will control. In addition, the cross over option must be activated.
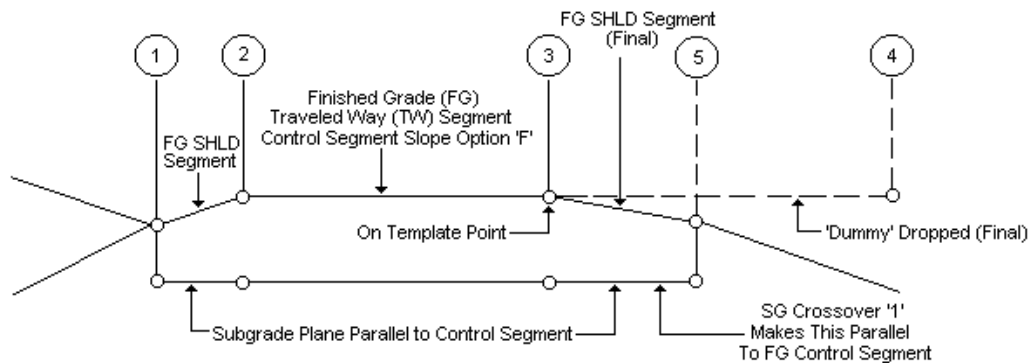
Use of the off template control option is not dependent on the use of the subgrade cross over option, nor is the use of the generic F segment slope option. The following examples show the use of the off template control option, without using the other options.

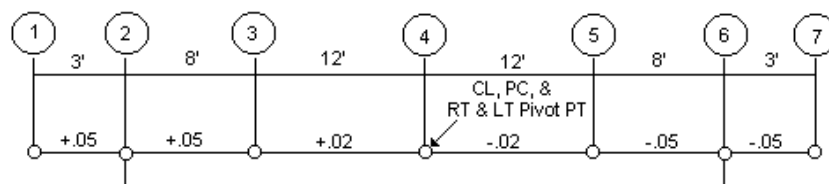Use of the segment slope option F, but not the subgrade cross over option:
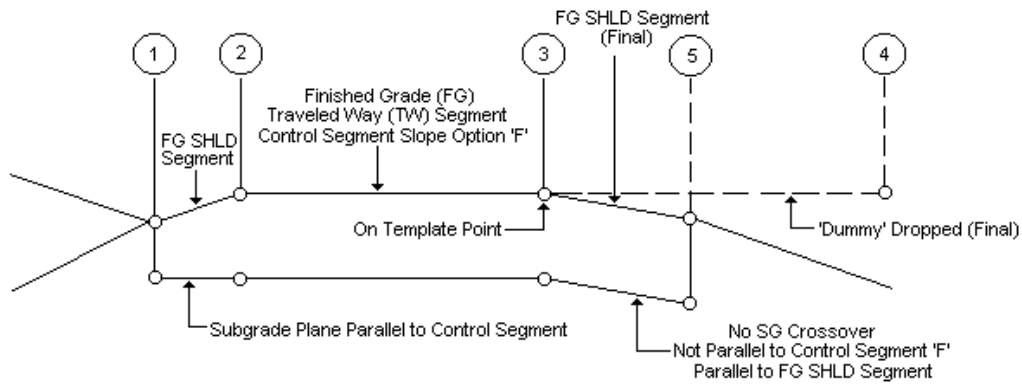
Use of neither the segment slope option F or the subgrade cross over option:
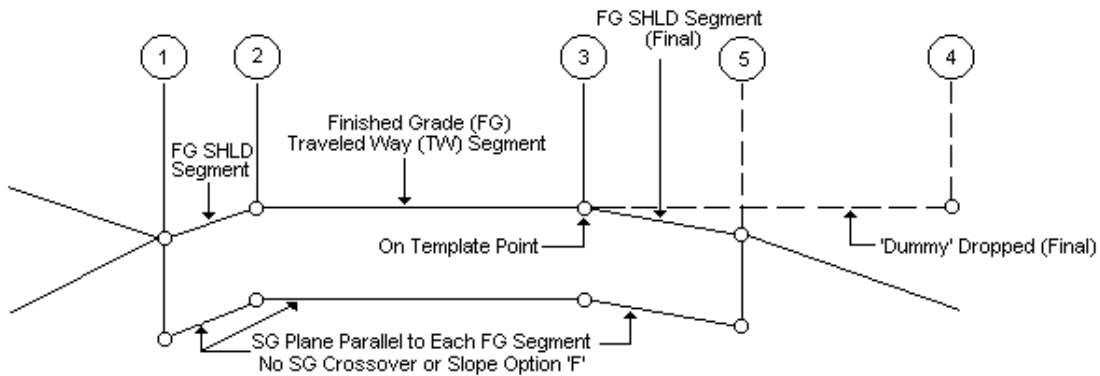
Trenched Subgrade

To use the trenched subgrade feature, a finished grade template must be defined, as shown in the following example.

Three basic shoulder point configurations are supported for trenched subgrades - C, D and F. A description of each type follows. The basic configurations are applied only to the first template segment, leftmost, or the last template segment, rightmost.

Shoulder Point Type C

The end of the leftmost segment and/or the beginning of the rightmost segment are designated as the points where the vertical subgrade segment (choker) is built when the roadway is in cut (always). It is also where the fill choker is built, unless overridden by the flat slope criteria. With a finished grade template described, these points are also the cut shoulder points.

The beginning of the leftmost segment and/or the end of the rightmost segment is designated as the finished grade fill shoulder point. When the fill choker option is overridden by the flat slope criteria (no choker built), the fill subgrade shoulder point becomes a subgrade point at the intersection of the grading plane and the sideslope. The intersection calculations for the sideslope are from the original finished grade fill shoulder point.
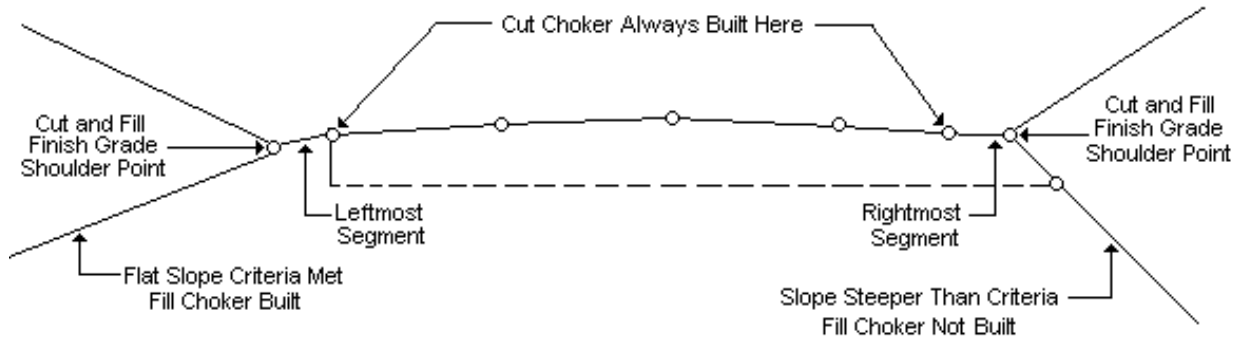
SHOULDER POINT TYPE C
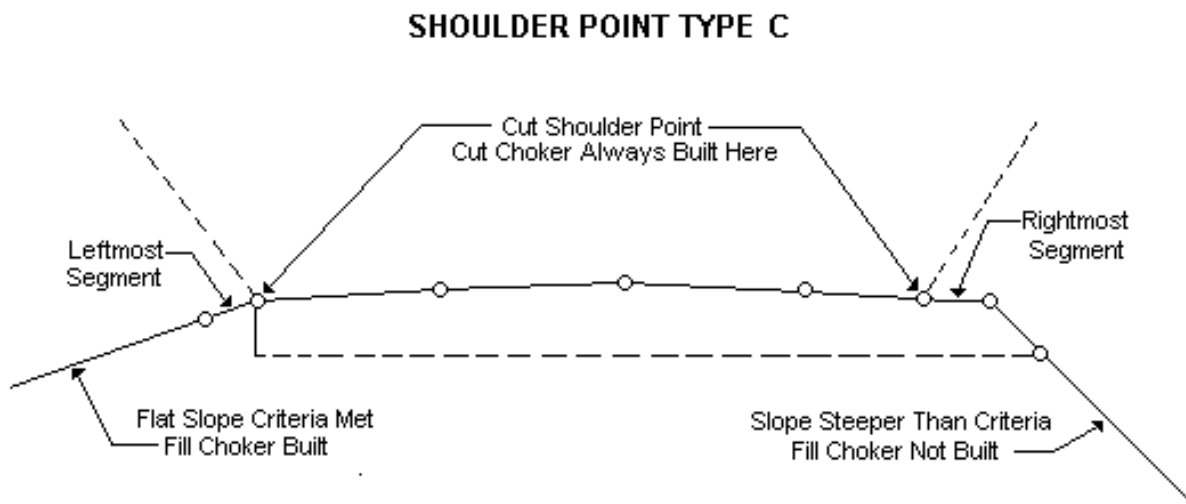
Shoulder Point Type D

The end of the leftmost segment and/or the beginning of the rightmost segment are designated as the points where the choker is built when the roadway is in cut (always). It is also where the fill choker is built, unless overridden by the flat slope criteria.

The beginning of the leftmost segment and/or the end of the rightmost segment are designated as the cut subgrade and finished grade shoulder point(s) (always), and the finished grade fill shoulder point. When the fill choker option is overridden by the flat slope criteria (no choker built), the fill subgrade shoulder point becomes a subgrade point at the intersection of the grading plane and the sideslope. The intersection calculations for the sideslope are from the original finished grade fill shoulder point.
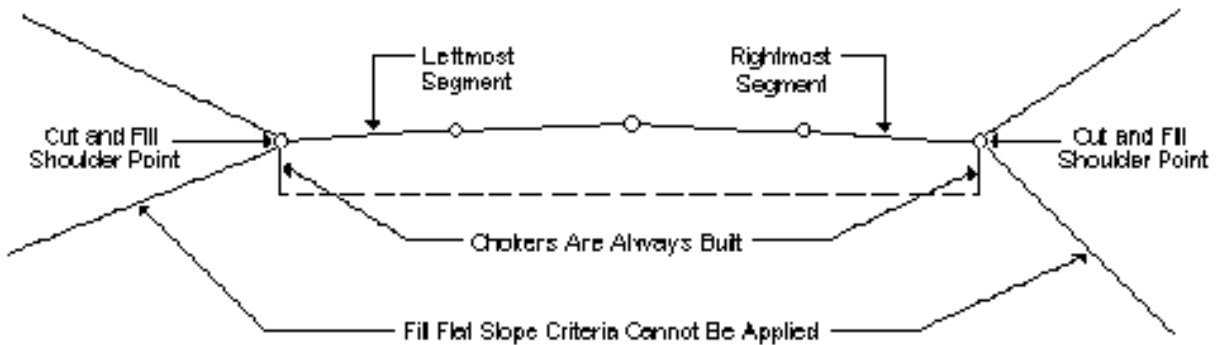
SHOULDER POINT TYPE D

Shoulder Point Type F

The beginning of the leftmost segment and/or the end of the rightmost segment are always designated as the points where the choker is built for both cut and fill situations, and are also the shoulder points (both finish and subgrade) from which the sideslope selection process begins. The flat slope criteria option is not necessary when using shoulder point type F.
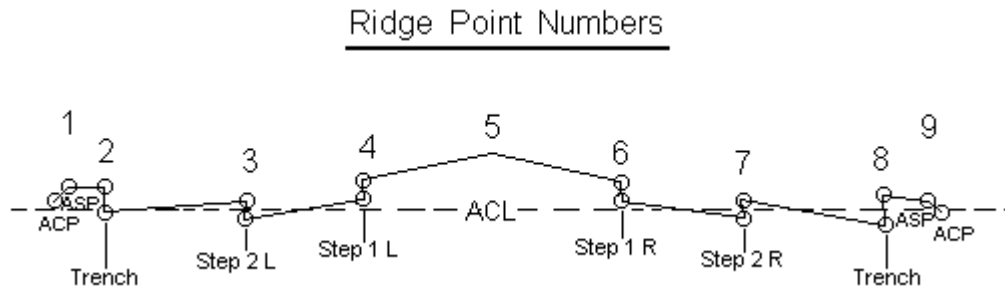
SHOULDER POINT TYPE F

Flat Slope Criteria

The flat slope criteria establishes when a fill choker will be built (shoulder point types C and D). The process checks the calculated sideslope ratio. If the slope ratio is the same as or flatter than the specified criteria, a fill choker will be built.

Stepped Subgrade

Ridge Point Numbers

The stepped subgrade feature allows the designer to define varying depths of trenching to account for shoulders, truck lanes, etc. Figures E-3 and E-4 show examples of the two capabilities. Up to ninety-nine (99) different levels (steps) may be defined per side of the template. The stepped subgrade feature works in concert with the trenched subgrade process.

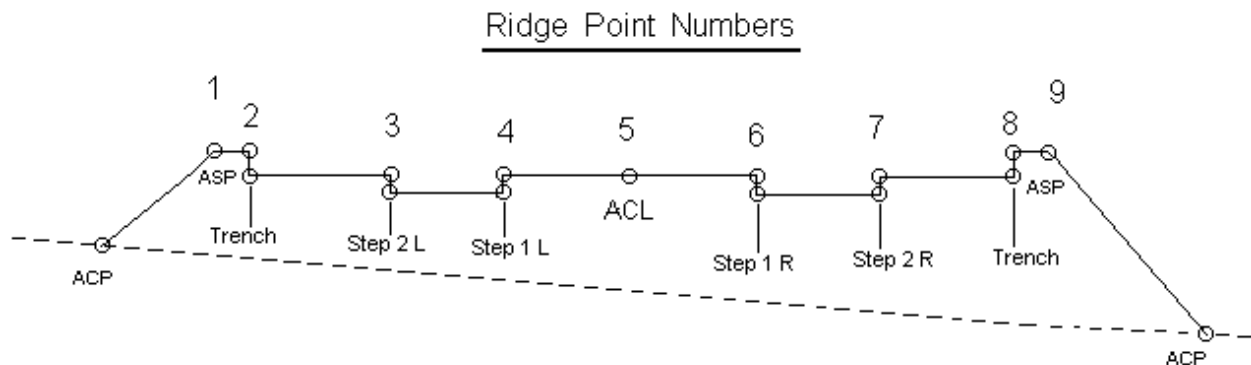Figure E-3 - Stepped Subgrade Example
Normal Crown

Ridge Point Numbers

Figure E-4 - Stepped Subgrade Example
Superelevated

TEMPLATE STATIONS

Since a template defines the shape of a roadway at only one station, it takes two template descriptions to define a section of roadway. Templates at any two successive stations must always have the same number of roadway segments. Slopes or distances, or both, for any roadway template segment may vary between templates as shown.
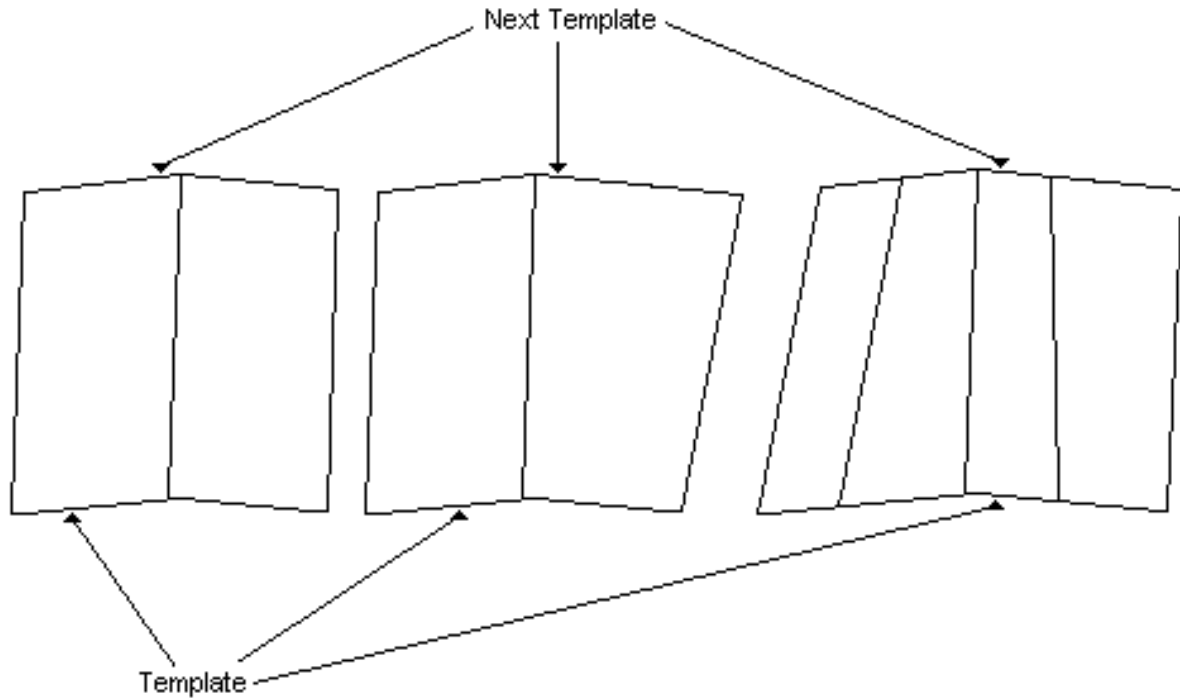
Thus, if the roadway shape is constant from beginning to end, one template shape would describe the whole roadway. This template shape must be applied at the beginning and end stations for the roadway. If there are transitions in shape, additional templates will be needed. It is not necessary to use templates to accomplish normal superelevations and widenings.

Traditionally within IGrds, the segment transition between template stations is calculated by performing a linear interpolation of the relative offsets and elevations between the beginning and ending template shapes, thereby generating relatively linear ridgelines. If the segment width does not vary, then the segment slope also varies linearly. However, if the segment width does vary, then the segment slope varies non-linearly. Some agencies prefer that the segment slope vary linearly, which, in this case, would mean that the ridgeline would vary non-linearly.

There is a flag in the design criteria table (ha.tbl) that controls the transition method used for template (and superelevation). If the flag is set to normal (0), then the template transition is performed in the traditional fashion. If the flag is set to alternate (1), then the template transition is performed by performing a linear transition of the segment slope.

Since every section of roadway must be defined by two templates which have the same number of roadway segments, it is necessary to have a method to change the number of roadway segments. This is done by entering two templates at the same station. The two templates should have the same shape, but differ in number of segments. This can be accomplished by defining multiple equivalent segments or dummy, or zero width, segments in the proper sequence to achieve the desired results.
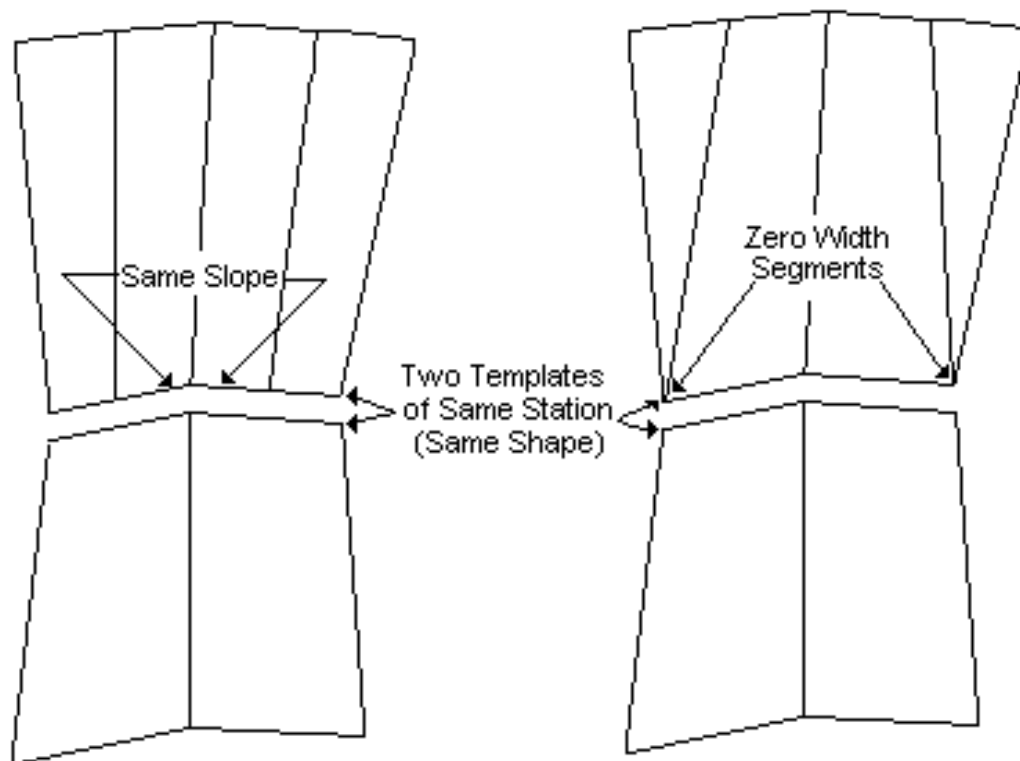
A table of typical templates is created. Any template in the table can be used by any roadway.

For all elevation computations involving command structured language (IGrds/AN option), the profile grade elevation correction and template surface depth are not used in the computations.