CHAPTER 5

ROADWAY DESIGN DATA

In this Chapter, design data refers to all of the data that contributes to the creation of design cross sections. These data specify the three dimensional aspects of roadways, from catch to catch. They are user defined but, in some cases, they can be automatically generated based on design criteria. It is important to understand how IGrds works with the design data to combine various data to generate design cross sections.

Design cross sections are assembled from three basic components which are associated with a terrain cross section. They are:

Templates	-	define the roadway surfaces
Medians	-	connect adjacent roadway surfaces
Sideslopes	-	connect roadway surfaces with the terrain cross section

These components are shown in Figure 5-1. NOTE THAT THE TERM "TEMPLATE" IS NOT USED TO REFER TO THE ENTIRE DESIGN CROSS SECTION.

The IGrds Design Data Manager provides for creating, modifying, viewing and selecting templates, medians and sideslope shape definitions. It also provides for creating, modifying and reviewing other design data and earthwork quantity data as shown here.

Template Shape Stationing	Geometric Template Modification
Sideslope Shape Stationing	Compaction Factors
Median Shape Stationing	Added Quantities
Superelevation	Surface Material Removal
Special Ditch Grades	Template Subcut
Widening	Top Soil Placement
Erosion Control Ditches	Choker
Right-of-Way	Slope Rounding
Maximum Slope Intercept	Stepped Subgrade
Design Exceptions	Pavement Structure Quantities

Some of the design data can be generated automatically based on design criteria tables in conjunction with horizontal and vertical alignments. A section on Automatic Generation of Design Data is included later in this Chapter.

Complex interaction among IGrds processes is needed to compile a design cross section. A brief discussion of these processes and how they work together follows to provide the overall picture. More detail on these processes is given later in the Manual.

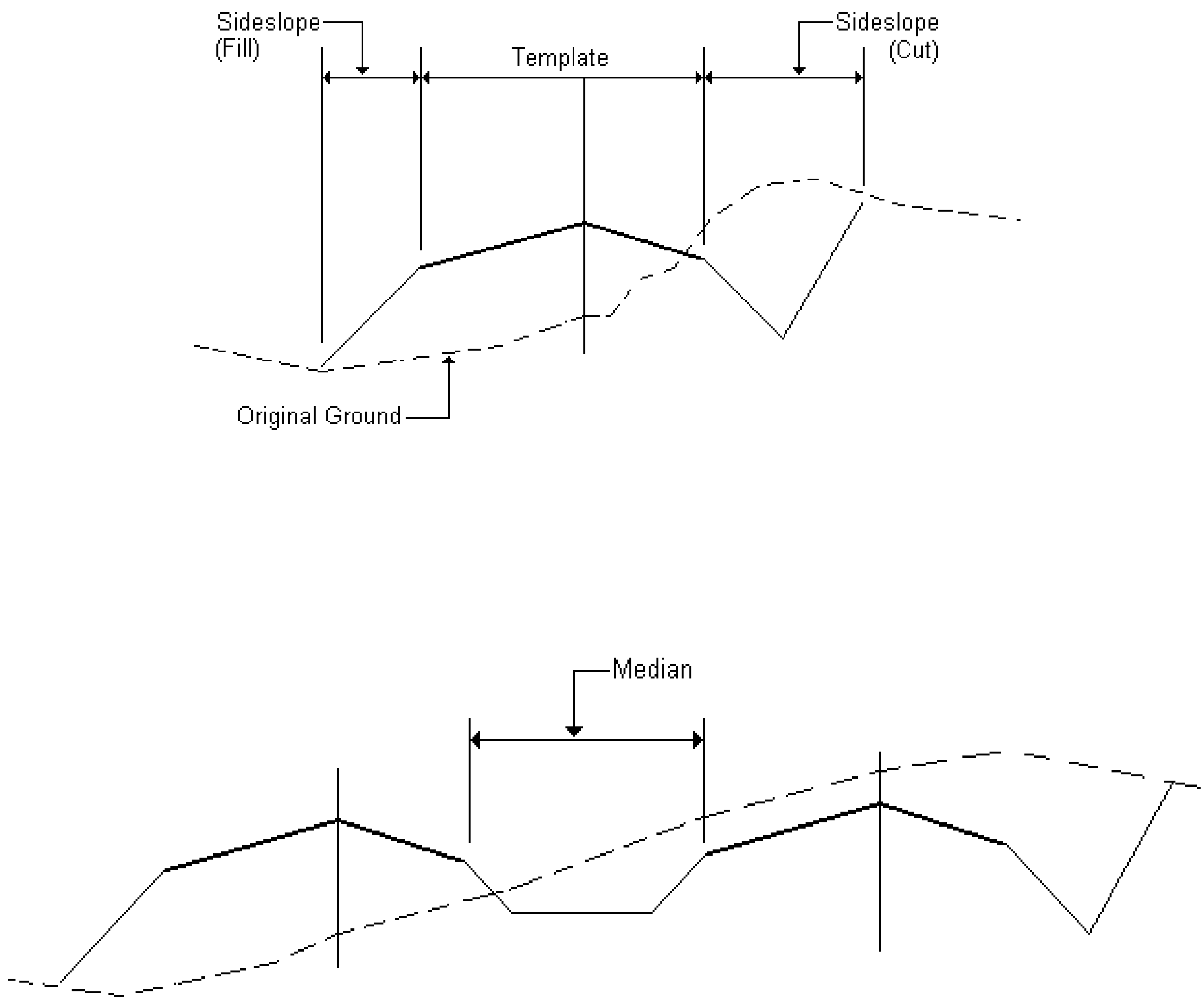
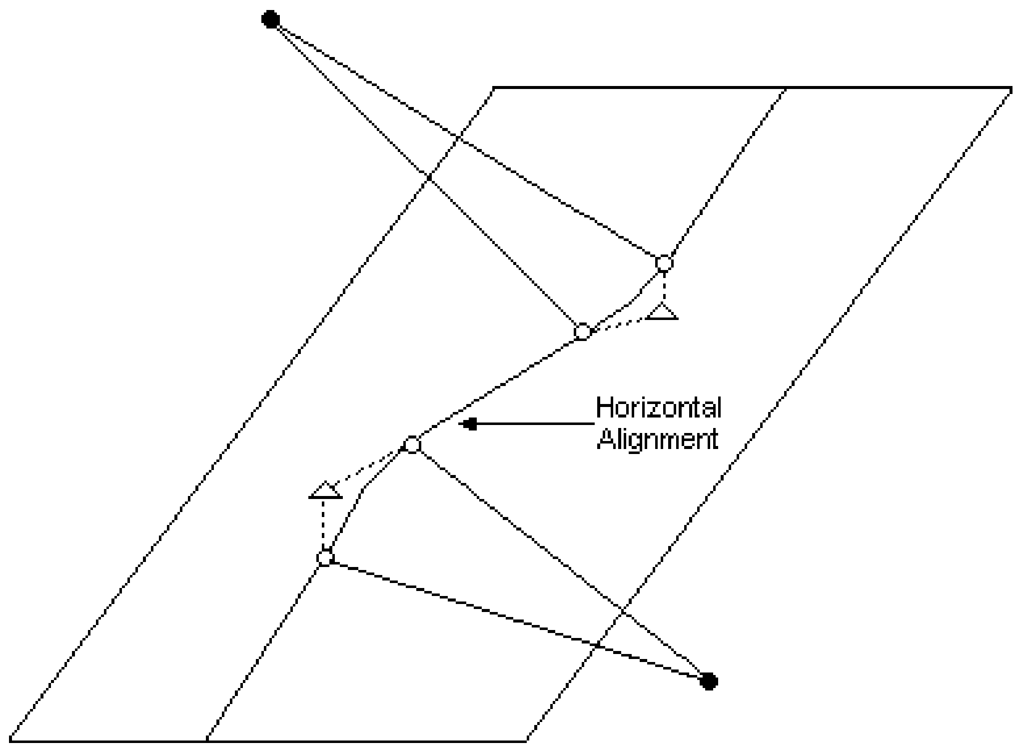


Figure 5-1 - Design Cross Sections

HORIZONTAL ALIGNMENTS

Horizontal alignments define the path of a roadway. Design cross sections may include from one to six roadway surfaces. Each design roadway follows an independent horizontal alignment. Design alignment stationing must increase in the same direction as baseline alignment stationing. Horizontal alignments are made up of straight lines, spiral transitions and circular segments. They are defined in the horizontal plane, as illustrated here, by specifying PI locations and curve characteristics. Horizontal alignments are discussed in more detail in Appendix B. Also, see the section entitled Automatic Generation of Design Data, later in this Chapter.

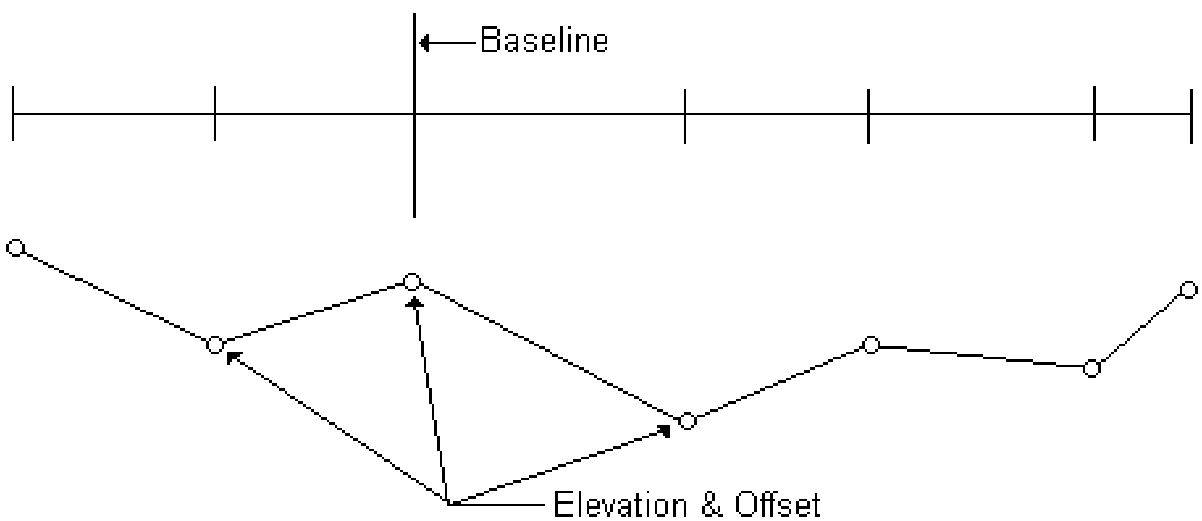


GEOMETRY

Defining the PI locations for a horizontal alignment may require geometric computations. These computations may relate to survey data, planimetric maps, traverses, known points or even from other alignments. The broad general geometry calculations of IGrds may be used to help define horizontal alignments, as well as for many other purposes such as right-of-way parcels, and pavement layouts.

TERRAIN CROSS SECTIONS

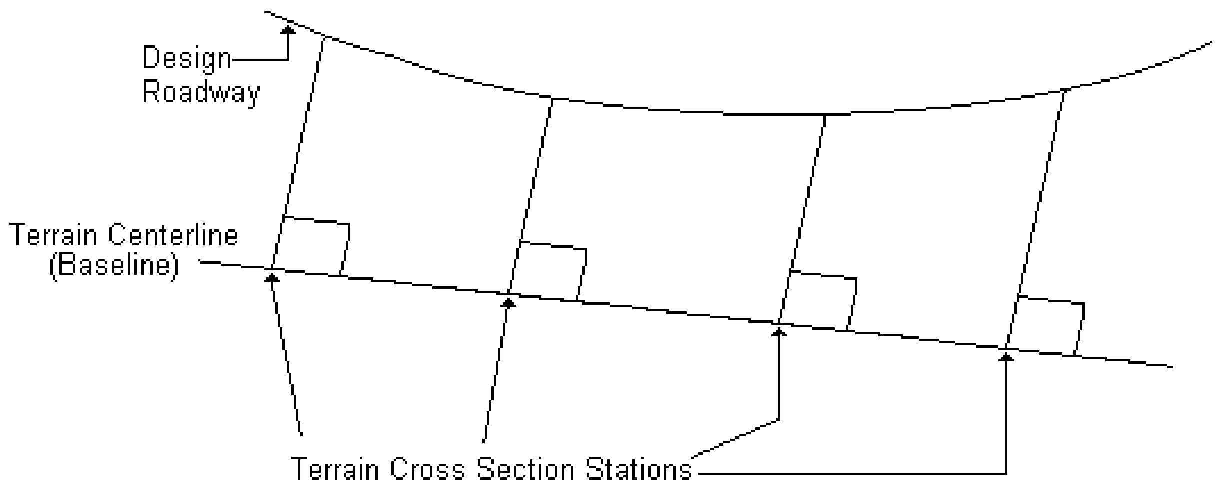
Design cross sections are always created in conjunction with a terrain cross section. A terrain cross section lies in a vertical plane which is perpendicular to its baseline (alignment). It consists of a series of terrain points defined by their elevations and offset distances from the baseline, as shown here.



Terrain cross sections are discussed in more detail in Chapter 4 and in the IGrds/AN Option User Manual.

HORIZONTAL POSITION CALCULATIONS

Since each design roadway can have an independent alignment, it is necessary to locate the centerline points with reference to the baseline in each individual cross section plane. A horizontal position calculation process computes the horizontal distance from the baseline to the other design alignments at the terrain cross section stations. Within the IGrds/IG Option, the horizontal position calculation process is performed automatically as required.

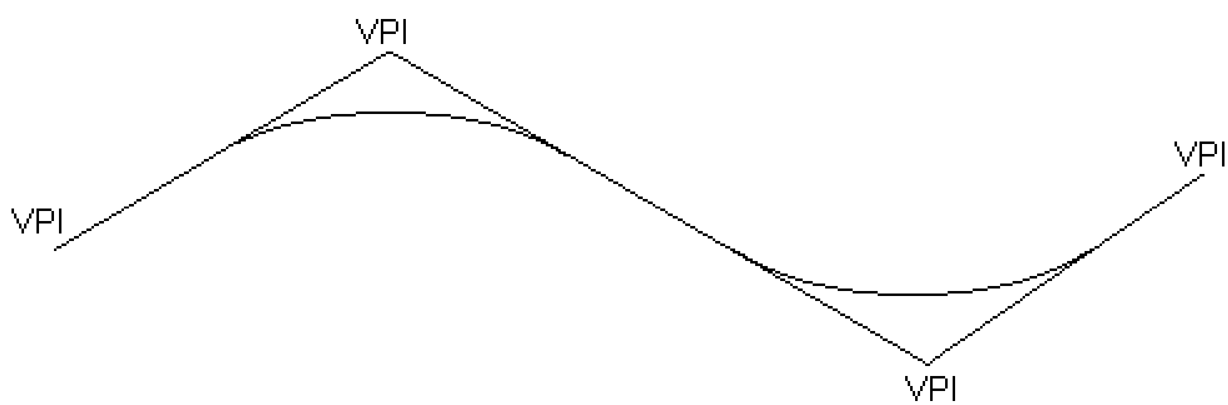


TERRAIN PROFILE

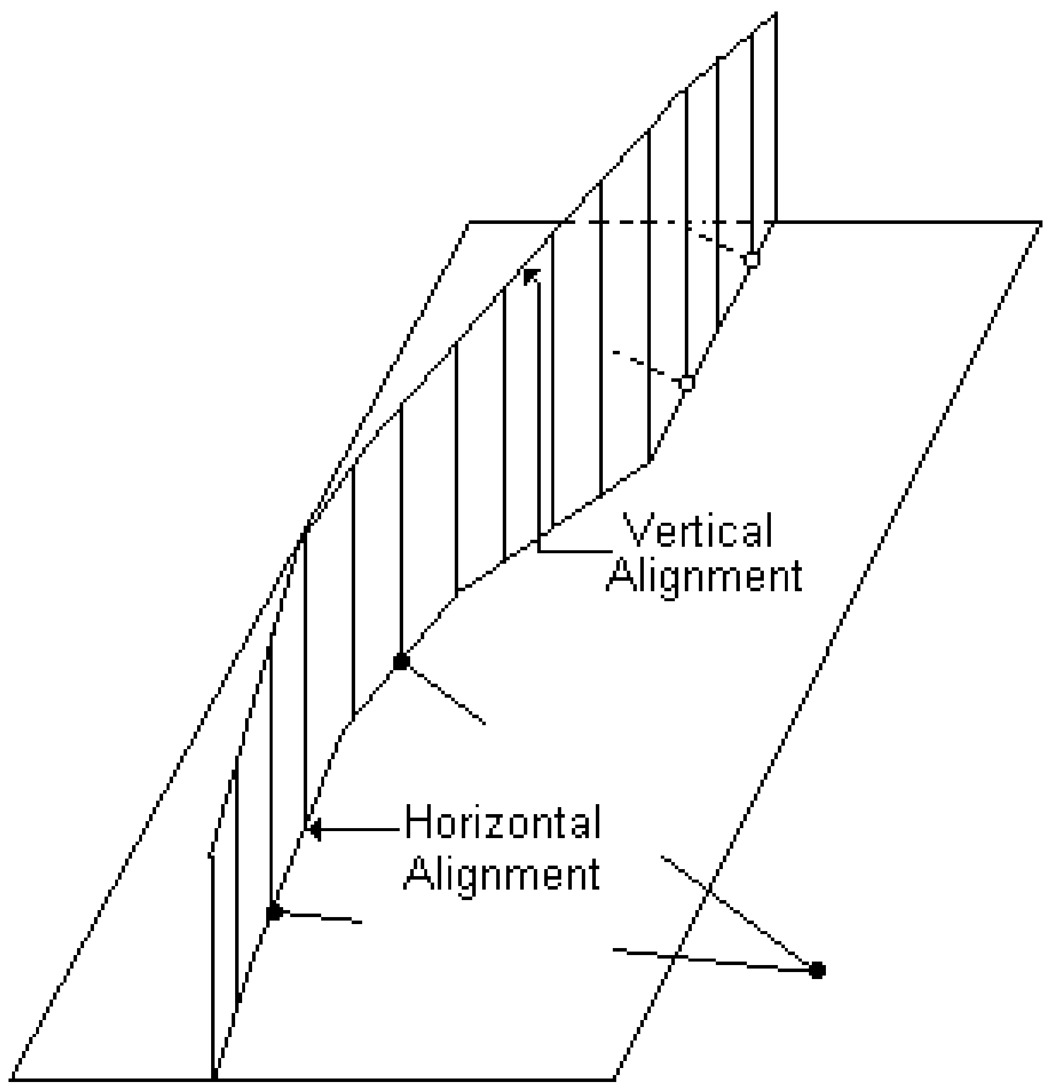
Profiles of the terrain along or parallel to a roadway alignment are helpful in establishing vertical alignments for the roadway. A terrain profile must be projected on a given vertical surface, as described below under Vertical Alignment.

VERTICAL ALIGNMENT

Vertical alignments define the path of the roadway surface in the vertical plane just as horizontal alignments do in the horizontal plane. Vertical alignments consist of straight segments and parabolic curves in a vertical plane. VPIs for each design roadway are defined by station and elevation, and, optionally, the vertical curve length. Within IGrds/IG, design profiles can be defined using dynamic tools similar to the MicroStation “Smartline” tool. See the IGrds IG User Manual, the section entitled Automatic Generation of Design Data later in this Chapter, and Appendix D of this document.



Actually, the vertical alignment lies in a vertical surface which follows the horizontal alignment, as illustrated here. The vertical alignment need not fall precisely along the horizontal alignment since it may be tied to different points on the template. The IGrds/IG Option includes several vertical geometry commands to assist in defining vertical alignments. See Appendix D for a detailed discussion of vertical alignments.



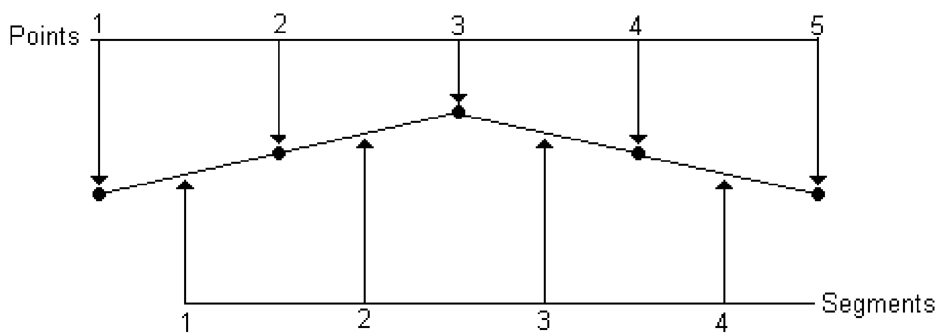
TEMPLATE PROCESSES

The template processes are related to the roadway surface. They define:

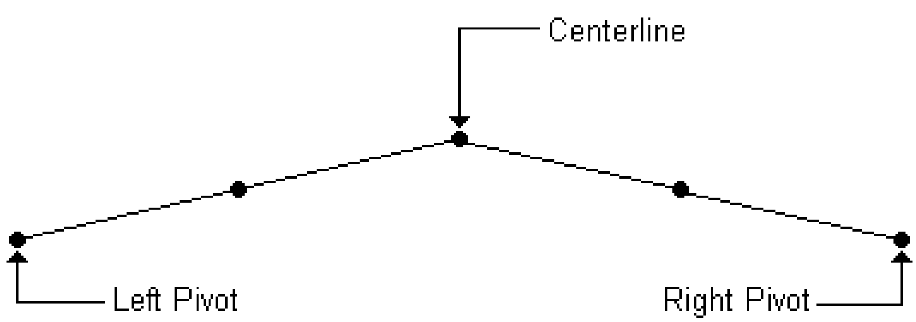
- Template shapes (patterns)
- Stations where shapes apply
- Modifications of the shape for superelevation, widening, and other ridgeline controls
- Specialized subgrade shape controls

Template Shapes

The designer defines and stores tables of template shape patterns to be applied at desired locations. A template shape is a series of slopes and distances (segments) which define the normal roadway shape, as shown here.



The end points are called shoulder points. The shape definition also designates the points which coincide with the horizontal and vertical alignments (centerline and profile grade points). These points locate the shape in space. It is also necessary to indicate points about which superelevation will be rotated (pivot points).



The designer may define either finish grade or subgrade templates. For finish grade templates, the designer specifies a subgrade depth, to, in effect, lower the finish grade template for earthwork calculations. See Appendix E for a detailed discussion of templates.

Template Stations

To completely define the roadway surface, the designer must enter the stations where template shapes apply on each roadway. The system transitions template segments automatically between different shapes. Thus, the system puts together the entire roadway surface from template shapes and stations, and horizontal and vertical alignments. See Figure 5-2.

Superelevation

IGrds uses the designer's instructions to modify the roadway surface by superelevating on horizontal curves. The specification includes full superelevation slope rates and transition lengths on each end of the curve. The system then automatically applies these specifications at each design cross section to modify the roadway surface. Exceptions to the normal superelevation application for each template segment are controlled by the user with segment options. See Appendix F for a detailed discussion of superelevation. Also, see the section entitled Automatic Generation of Design Data, later in this Chapter.

Widening (Widths and Transition Lengths)

This template process lets the designer modify segments of the roadway template shape. Similar to superelevation, full widening and transition lengths are input. See Appendix G for a detailed discussion of widening. Also, see the section entitled Automatic Generation of Design Data, later in this Chapter.

Geometric Template Modification (Template Point Control by Geometry Elements)

This IGrds/IG process provides a method for defining template segment widths and/or template point elevations using 3D MicroStation or IGrds geometry elements. The process is similar to widening, except that it can be used to modify all roadway segments in both width and elevation. It provides the means for defining elevation and/or lateral shifts in template points over a specified station range based upon the 3D location of line, arc, or chain geometry elements defined along the roadway. See Appendix G for a detailed discussion of geometric template modification.

The final product of the template process is the design roadway surface, which is illustrated in Figure 5-3. This Figure shows how superelevation and widening work to automatically modify template shapes.

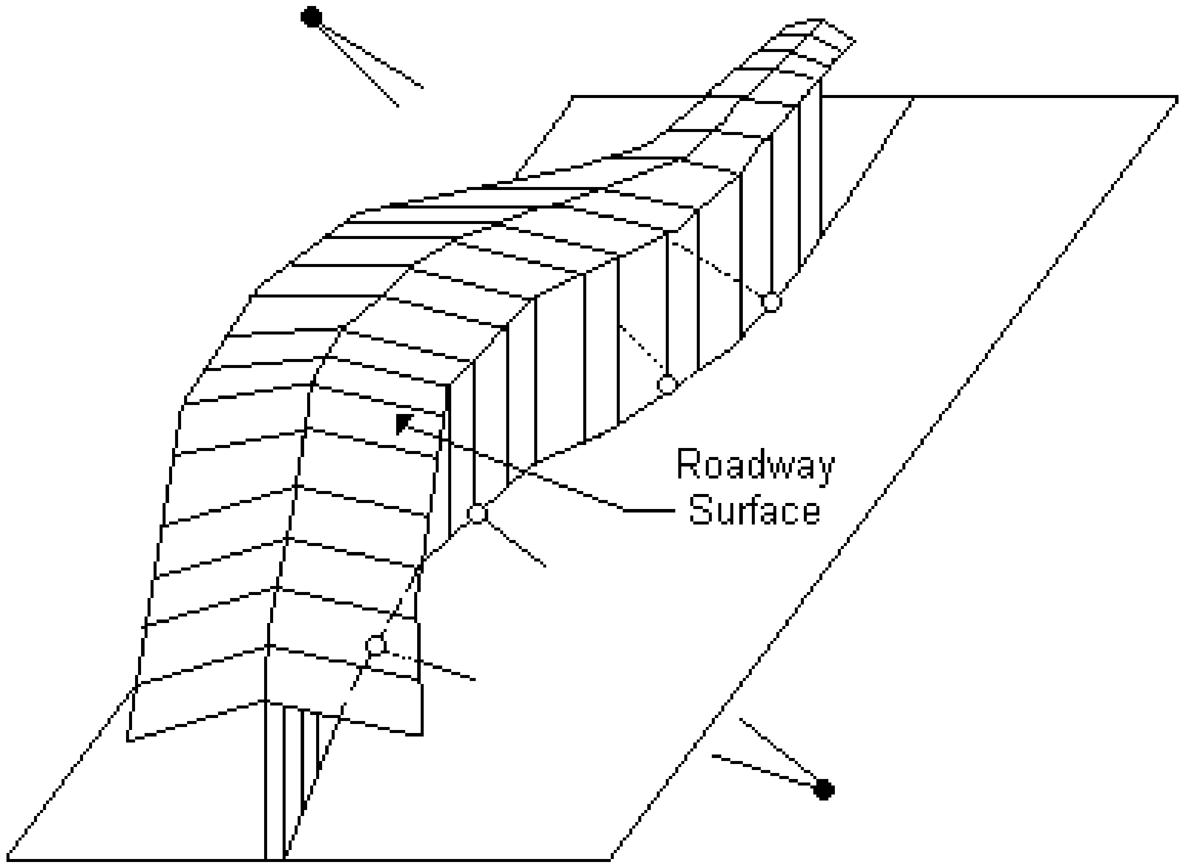


Figure 5-2 - Roadway Templates

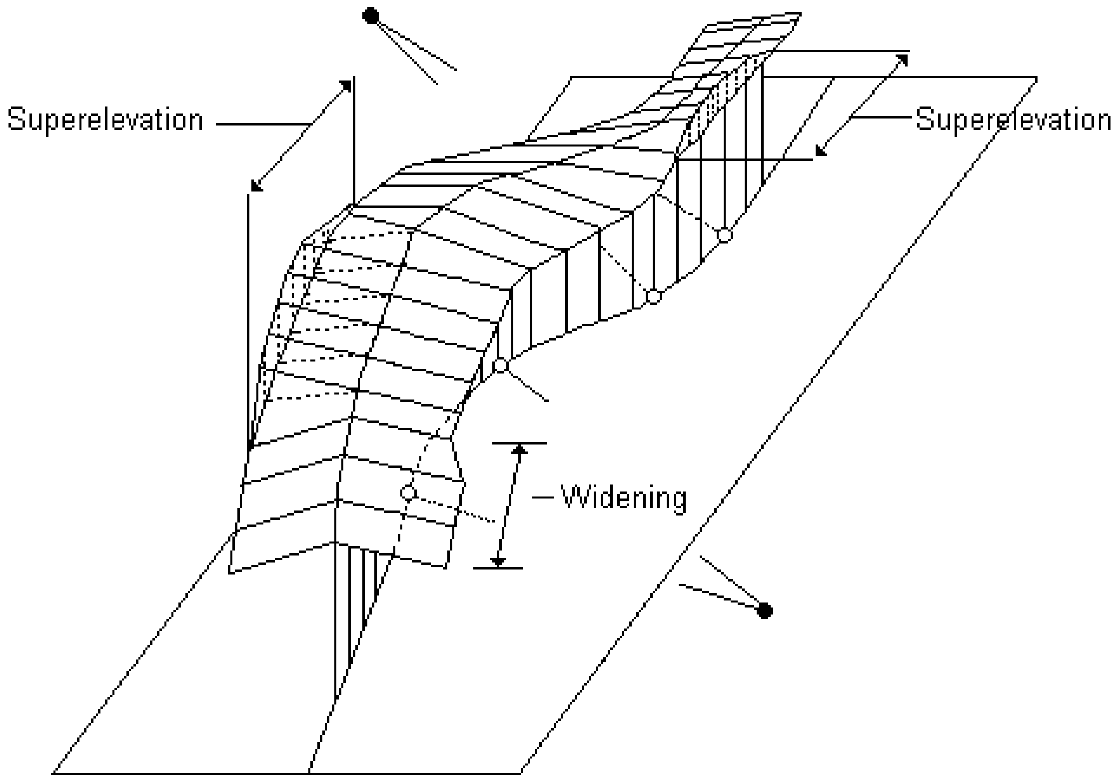


Figure 5-3 - Roadway Templates with Superelevation and Widening

MEDIAN PROCESSES

Median processes contribute to design cross sections by connecting the shoulder points of adjacent roadways.

Median Shapes

Median shape patterns are stored in tables for later use in the same way template shapes are stored, but the shape criteria is more flexible. Since roadway surfaces are controlled by their independent horizontal and vertical alignments, the horizontal and vertical distances between shoulder points can vary considerably. The median shape criteria handles a multitude of variations.

Median shapes are made up of zero to three segments extending from each roadway. See Figure 5-4. The designer specifies width and slope of each segment and criteria about how the segments from each are to be modified when they intersect and when they do not. IGrds automatically combines the two sets of segments into a continuous link between the two roadways. It even handles cases where the two roadways overlap. This is explained in detail in Appendix H.

The median shape definition may include criteria for locating specially graded ditches, as discussed below.

Median Stations

The designer must specify the beginning and ending stations where a median shape applies. The desired shape is referenced by its number in the table. If desired, any or all of the segments can be linearly transitioned for a station range by defining a beginning and ending shape.

Special Ditch Grades

Median shapes normally include a ditch with the ditch elevation controlled by the elevation of the lowest adjacent roadway. The grade on the ditch defined by the median shape is usually adequate, but special drainage conditions may make a special ditch grade line necessary. In this case, the designer defines independent special ditch grade lines. Special ditch grades can be 3D MicroStation or IGrds geometry elements or grade lines similar to vertical alignments without vertical curves. IGrds will then modify the median pattern to include the proper ditch elevation(s). Criteria included in the applicable median shape determine the lateral location of the ditch(es). See Appendix I for a detailed discussion of special ditch grades.

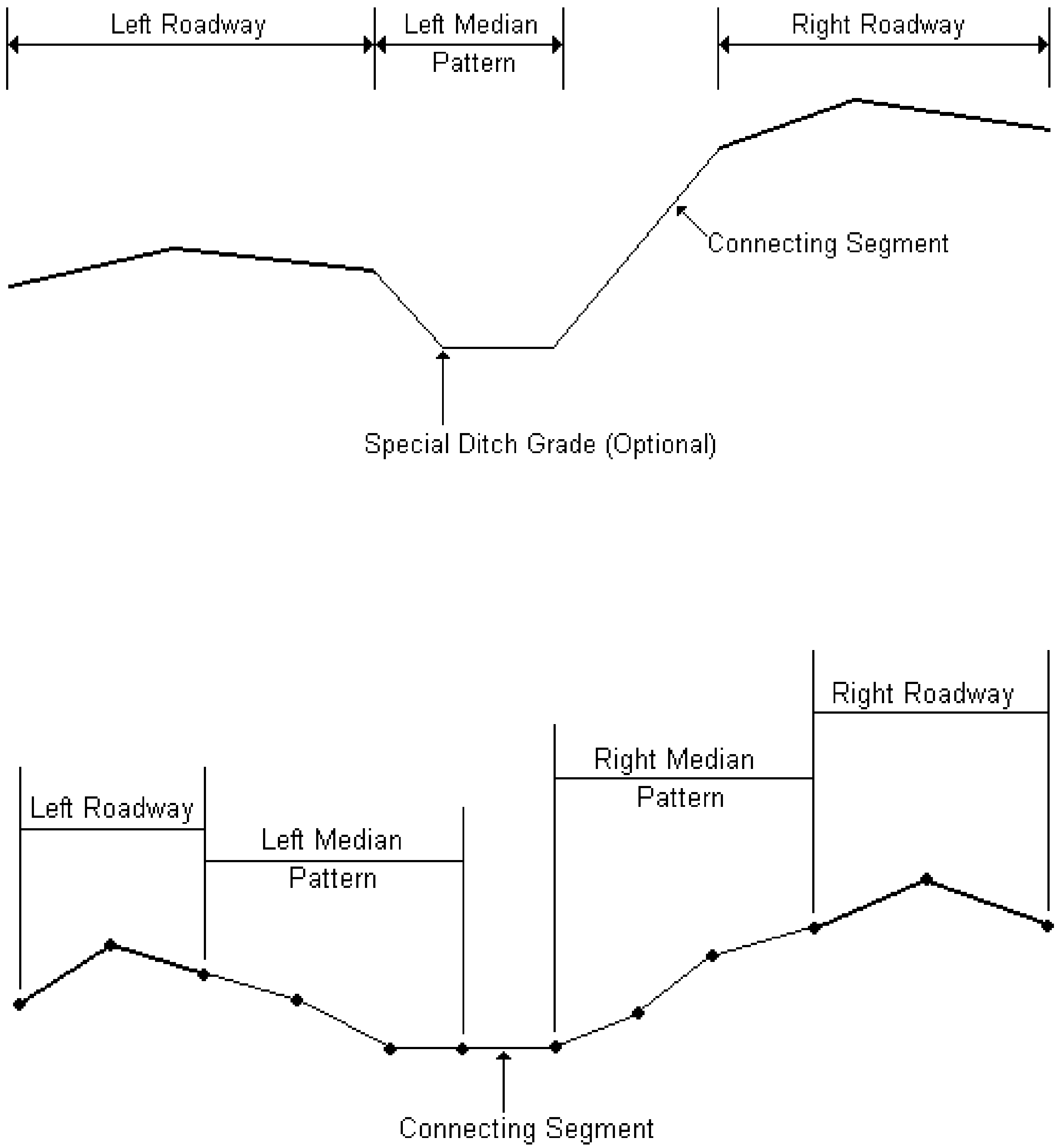


Figure 5-4 - Median Examples

SIDESLOPE PROCESSES

Sideslope processes complete the design cross section by connecting the remaining shoulder points with the terrain cross section.

Sideslope Shapes

Sideslope shapes also consist of one or more segments beginning at a roadway shoulder point and extending to an intersection with the terrain cross section. Like template and median shapes, they are stored in tables for recall. Since roadway shoulder points may fall above or below the terrain cross section, two types of sideslope shapes must be defined - cut and fill (see Figure 5-5). The system determines the appropriate shape, cut or fill to be used to complete the section.

Both types of sideslope shapes may have one or more fixed segments extending outward from the shoulder point. There must be at least one variable slope beginning at the hinge point (end of last fixed slope) (see Figure 5-5).

Normally, any fixed slopes are built as defined and then one of the variable segments is extended from the hinge point to the catch point (the point where it intersects the terrain section). The variable segment used will be selected based on the vertical distance between the hinge point and the terrain section (see Figure 5-6). It is also possible to define fixed segment criteria such that they catch (intersect with) the terrain section. Sideslope shape criteria also defines the location of special ditches, as described below.

Sideslope Stations

The designer must specify the beginning and ending stations where sideslope shapes apply. Previously stored cut and fill sideslope shapes must be defined to cover all applicable locations. See Appendix J for a detailed discussion of sideslopes. If desired, any or all of the sideslope segments can be linearly transitioned over a station range by defining a beginning and ending range.

Special Ditch Grades

Cut sideslope shapes normally include a ditch. The ditch elevation parallels the shoulder point elevation. As with medians, special drainage considerations may make special ditch grades necessary. Special ditch grades for sideslopes are defined in the same way as medians. When special grades are defined, IGrds will modify the normal sideslope shape to include the proper ditch elevation(s). Criteria included in the applicable sideslope shape determines the vertical and/or lateral location of the ditch(es). Up to ten special ditch grades can be defined for both sides of any design alignment. See Appendix I.

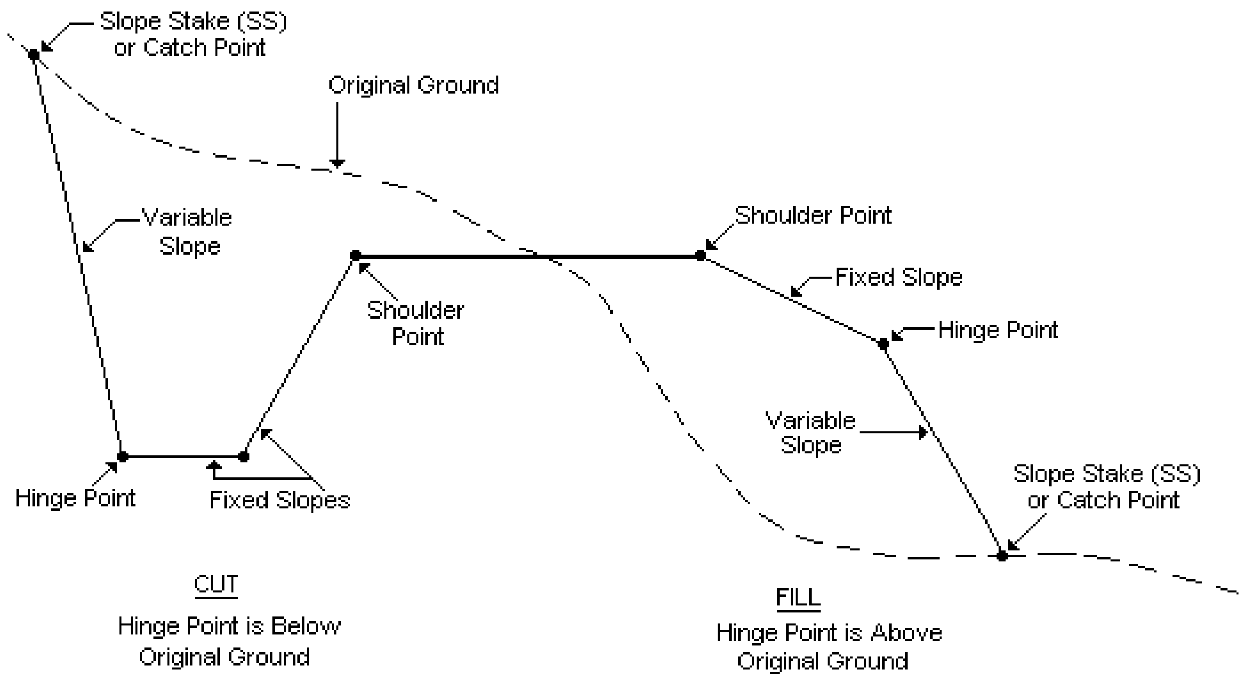


Figure 5-5 - Sideslope Shapes

- If the vertical distance on the sideslope is 5' or less, use a 6:1 slope.
- If the vertical distance is greater than 5' but no greater than 10', use a 4:1 slope.
- If the vertical distance is greater than 10', use a 2:1 slope regardless of vertical dimension.

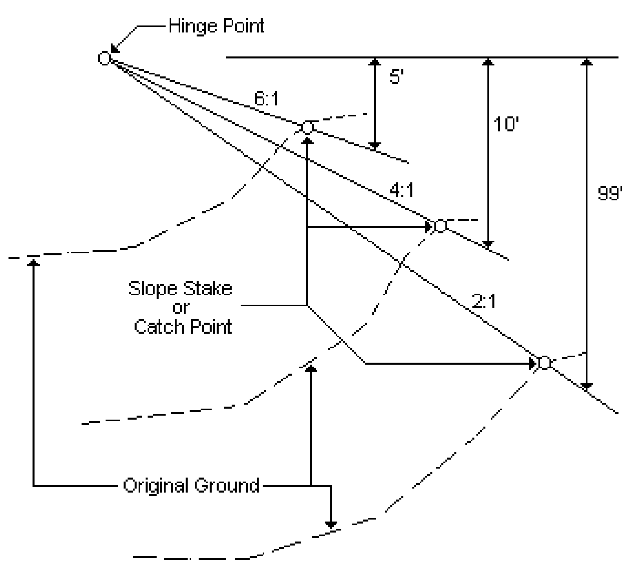


Figure 5-6 - Variable Segments

Erosion Control Ditches

Erosion control ditches can be specified for both the top of backslope (cut condition) or toe of slope (fill condition) over a given station range at a user defined distance from the catch point. Erosion control ditches are specified like any other cut pattern and can include both fixed and variable slopes. They can also include special ditch grades. See Appendix I.

Maximum Slope Intercept

In many cases, such as limited right-of-way, it is necessary to limit the maximum slope intercept - the maximum distance of the catch point from the roadway centerline. Maximum slope intercept may be specified by giving a distance (see Figure 5-7) from:

- roadway centerline
- shoulder point

Maximum slope intercept may also be defined by referencing MicroStation or IGrds geometry elements in the same fashion as geometric template modifications.

For a detailed discussion of maximum slope intercepts, see Appendix K.

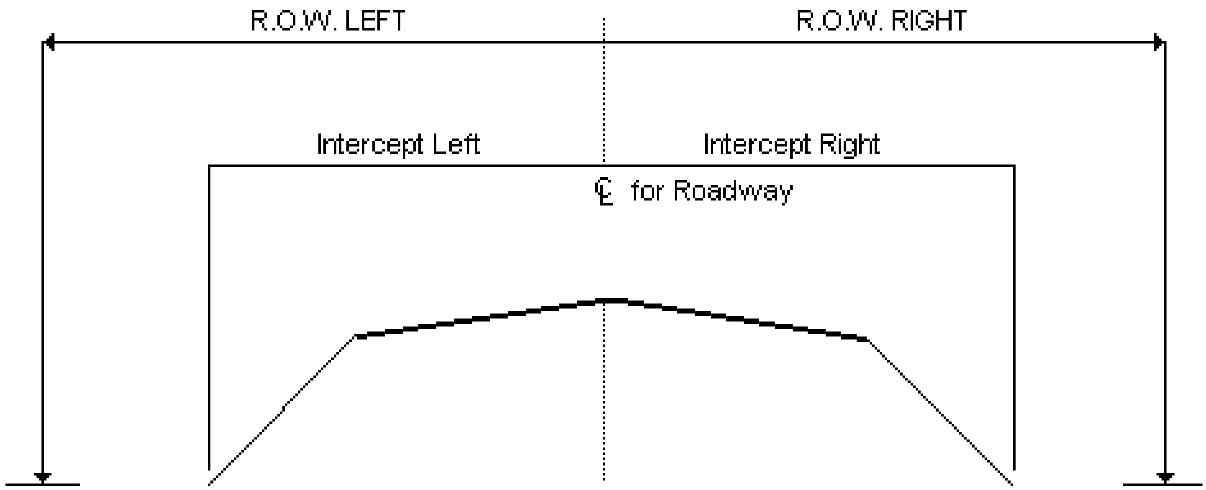


Figure 5-7 - Maximum Slope Intercept

OTHER DESIGN SECTION MODIFICATIONS

To this point we have discussed the designer specifications and how they interact to produce a design cross section. The discussion has been simplified to give the overall concept. Each of the processes mentioned has a variety of options the designer can exercise to modify the design cross section. In addition, there are special processes which modify the design section, such as:

- Off Template Control - see Appendix E
- Trenched Subgrade Provisions - see Appendix E
- Stepped Subgrade - see Appendix E
- Slope Rounding - see Appendix J
- Template Subcut - see Appendix N
- Surface Material Removal - see Appendix N

Several of these processes are illustrated in Figures 5-8, 5-9 and 5-10, and all are discussed in detail in the appropriate Appendices.

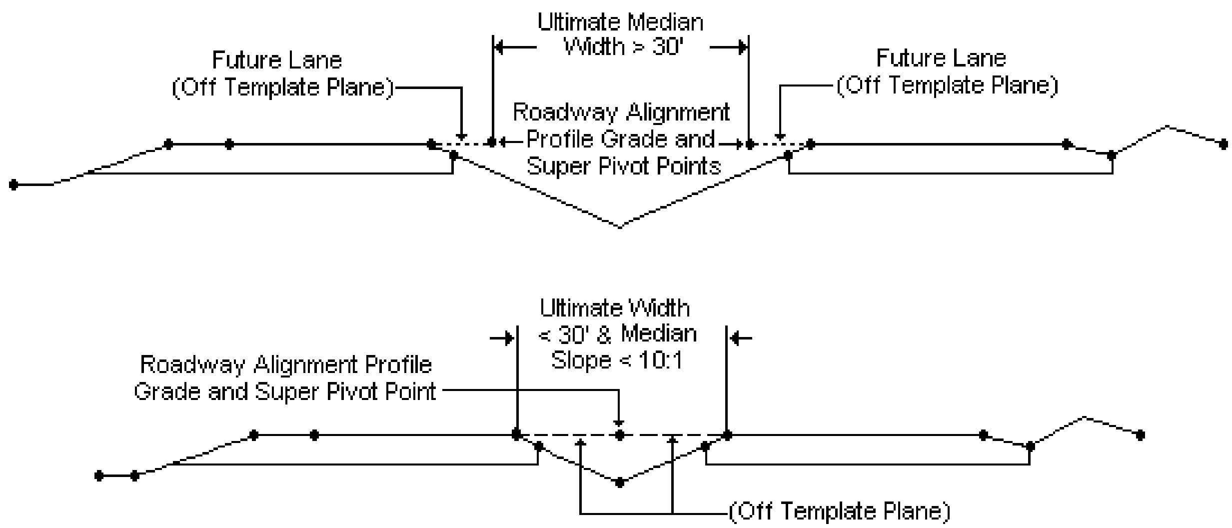


Figure 5-8 - Off Template Control

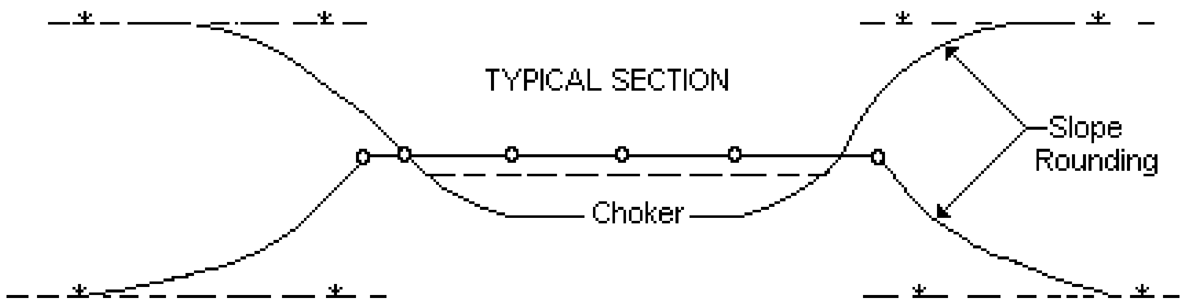


Figure 5-9 - Trenched Subgrade Sections with Slope Rounding

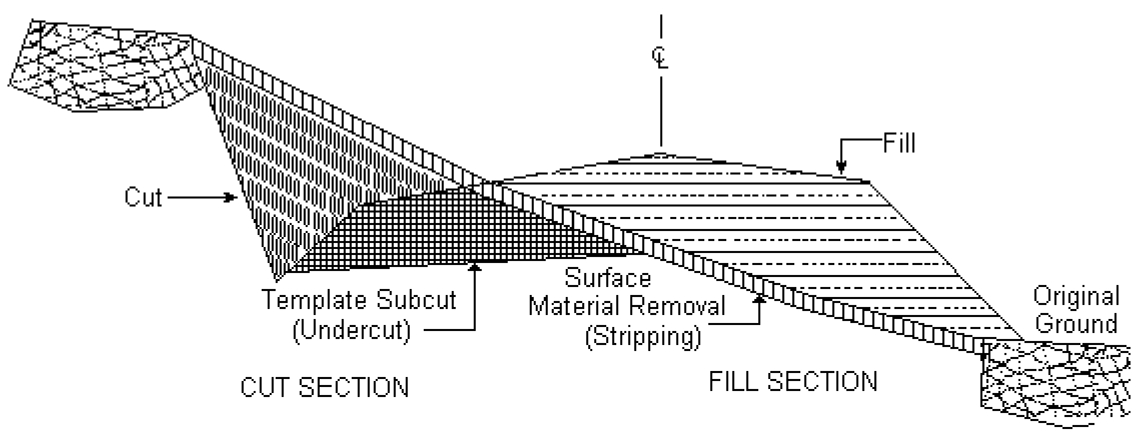


Figure 5-10 - Surface Material Removal and Template Subcut

AUTOMATIC GENERATION OF DESIGN DATA

Some design data types can either be entered or generated automatically. Automatic generation is an option which requires that design criteria be available. IGrds/IG provides for storing criteria from the Road Design Manual, or user agency criteria. The applicable criteria is then assigned to each PI within an alignment. From this criteria, the system can generate the following data:

- curve properties for horizontal PIs based on design speed
- superelevation data corresponding to curvature
- vertical curve lengths based on sight distance
- automatic widening on sharp horizontal curves

The required AASHTO Design Standards from the 1990/1994 and the 2001 versions of *A Policy on Geometric Design of Highways and Streets* are embodied in the design criteria table as separate portions. The standards to be used (1990/1994 or 2001) are user selectable and the indication of which standard to be used is stored in the project .ini file. The design criteria are associated with IGrds alignments using the roadway design parameters dialog box. Using these criteria and AASHTO standard methods and formats imbedded in the calculation processes, users are able to request automatic horizontal curvature, including spiral lengths, automatic superelevation and transition length calculations, automatic pavement widening on sharp horizontal curves, and automatic vertical curve length calculations and adjustments. Any automatically generated data can be modified as desired. The following paragraphs discuss the automatic calculation features in more detail. Also see Appendices B, F, and G.

Design Criteria Table

The design criteria table (ha.tbl) contains AASHTO Green Book standards for horizontal and vertical alignment related data in both Metric and Imperial units. The table contains horizontal curvature and superelevation criteria for rural, high speed urban and low speed urban design. It also contains criteria used in solving transition length calculations for all design conditions. Criteria used in determining if and how much pavement widening is required for sharp horizontal curves are included as well. Sight distance criteria (i.e., stopping, decision and passing) are included for automatic vertical curve length calculations. The table also contains various rounding factors and switches, default design parameters, and user defined template segment options. This design criteria table is an ASCII editable file that can be customized by user agencies whenever the agency's standards differ from the AASHTO Standards.

Roadway Design Parameters Dialog Box

The key to assigning attributes to an IGrds alignment is the roadway design parameters dialog box. The user can select default design parameters for particular classes of facilities, which loads the dialog box with the selected characteristics. The user is also able to select or modify design characteristics, including the roadway class, number of lanes, lane width, location and terrain from the option buttons. The available options for each of these elements come directly from AASHTO nomenclature and are stored in the design criteria table. Likewise, the user can enter or edit the maximum and minimum grades and, if 2001 standards are in effect, the design vehicle. The user is also able to select or edit other design parameters, including the maximum superelevation rate and design speed for the alignment. The maximum friction factor, running speed and desirable stopping sight distance are then displayed directly from the design criteria table. Finally, the user is able to select or edit the superelevation type (0-4) and, where appropriate, the crown runoff length (Type 0) or the normal crown cross slope rate (Types 1, 2 or 3). Most of these parameters can be assigned to individual PI's, as discussed in the User Manual.

The location option button sets the method to be used for superelevation and transition length calculations and controls which maximum e and design speed values are available. For example, if the user selects rural from the location option button, then the values for maximum e vary between 4% and 12%, and the values for design speed vary between 15 and 80 mph (20 and 130 Km/h if Metric). If the user selects low speed urban, then the values for maximum e vary between 0% and 6%, and the values for design speed vary between 15 and 45 mph (20 and 70 Km/h if Metric). Note: Not all design speeds are used if the 1990/1994 standards are in effect.

Automatic Curvature for Horizontal PIs

Based on the selected criteria for a PI within an alignment, the user can request automatic curve properties for a PI. The desirable radius for the design speed selected for the PI is automatically shown in the radius field. This value can be overridden by the user, if desired. Likewise, for spiral curves, the spiral length is automatically calculated based upon the number of lanes, lane width, and calculated superelevation rate for the curve and shown in the spiral length fields. These values can also be overridden by the user, if desired. If the user enters the curvature, then, during the create/update process, the radius is checked to see if it is less than the minimum radius. If so, the user is alerted. Similarly, the create/update process will check the minimum curve length for each PI based on design speed and type of facility. If the 2001 standards are in effect, the process also checks calculated or entered spiral lengths against the suggested minimum and maximum lengths and alerts the user as required.

Automatic Superelevation and Transition Length

Automatic superelevation and transition length computations can be requested by the user by selecting the automatic superelevation option when the alignment is being created or updated. For rural or high speed urban design conditions, the superelevation rate for a particular curve is calculated using the standard AASHTO process for development of the finalized super rate distribution known as "Method 5". Calculations are based on the curve radius, and the design speed, running speed, maximum superelevation rate, and maximum friction factor for the PI being processed. The transition length is calculated using the standard AASHTO method and the number of lanes, lane width, calculated superelevation rate, design and superelevation type. For low speed urban design conditions, the superelevation rate and transition length for a particular curve are calculated using the appropriate formulas from the AASHTO Green Book and the low speed urban criteria. See Appendix F.

Automatic Pavement Widening on Sharp Horizontal Curves

Pavements on curves are sometimes widened to make operating conditions on curves comparable to those on tangents. If automatic widening is desired, the user can request this by selecting the automatic widening option when the alignment is being created or updated. The standard AASHTO methodology is used, based on the selected AASHTO design vehicle and lateral clearances from the AASHTO Green Book. When 2001 standards are in effect, the design vehicle is selectable from the ha.tbl; for the 1990/1994 standards only one design vehicle is allowed. Other data used involves the number of lanes, lane width, design speed, and the radius of the curve being processed. See Appendix G.

Automatic Vertical Curve Lengths and Adjustments

Based on the selected criteria for an alignment, the user can request automatic vertical curve length calculations for any or all VPIs for an alignment. The user can specify whether passing sight distance should be considered. Using the appropriate formula, the process calculates lengths of sag or crest curve based on the sight distance, design speed and grades within the design criteria zone for the VPI being processed. The user can specify whether any or all curve lengths can be adjusted if there are curve overlaps. The process checks the computed grades versus the maximum and minimum specified grades for the alignment. The user is alerted if grades are violated. A report is provided that analyzes the vertical alignment on a PI-by-PI basis. The overlap adjustment strategy is discussed in detail in Appendix D.

DESIGN SEQUENCE

The designer supplies all of the data discussed to this point. IGrds provides help to accomplish data specifications. The next Chapter gives a summary of data related to design sections. The system then does all of the checking, management, and computations necessary to compile a complete design cross section. The complex interaction of IGrds processes is depicted in Figure 5-11. The designer provides that data and the system puts it together. Understanding the sequence of steps permits the designer to take advantage of the sequence on multi-stage construction projects. This will be discussed in the next section.

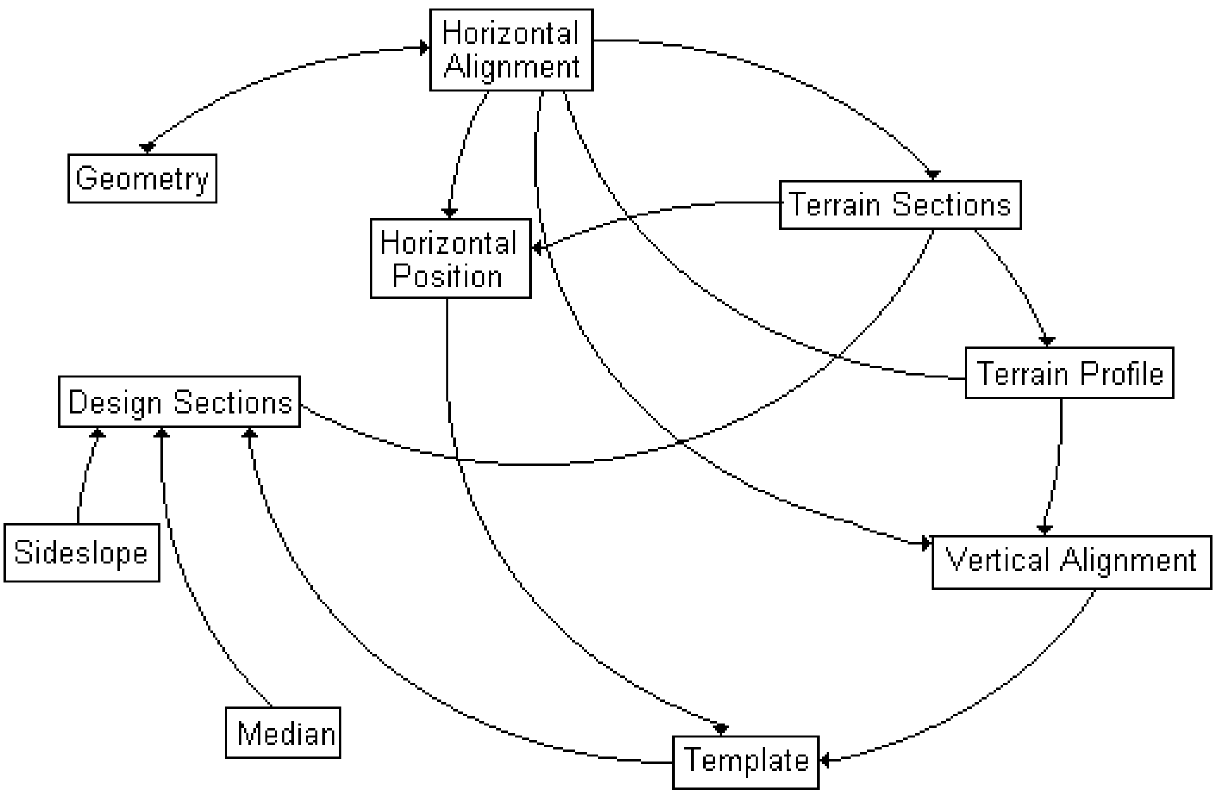


Figure 5-11 - Interaction of Design Section Processes

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