

AUTOCAD® CIVIL 2009 AND AUTOCAD® CIVIL 3D® 2009

Road Rehabilitation and Reconstruction with AutoCAD® Civil and AutoCAD® Civil 3D®

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Introduction

From an engineering standpoint, road reconstruction is often considered the most difficult type of road design to perform. Rather than dealing with the pristine geometry of new construction, the designer is faced with integrating the design into the irregularities of existing conditions. Because of this, each cross section of the road can be an individual design requiring special attention to cross slopes, pavement irregularities, and many other potential conditions. Despite these challenges, the designer is still required to produce an accurate design and an accurate account of the required material types and quantities. After reading this white paper, you will have the technical foundation to perform various types of road rehabilitation and reconstruction design with the help of AutoCAD Civil or AutoCAD Civil 3D.

AutoCAD Civil and AutoCAD Civil 3D software (collectively referred to in this document as “the Civil products”) comes equipped with subassemblies designed specifically for road rehabilitation and reconstruction design. It is capable of interacting with existing conditions, analyzing them, and responding in ways that suit the design intent. In this way, the designer does not have to approach each cross section as an individual design, but instead can configure these subassemblies to make design decisions automatically. The result is that with the help of AutoCAD Civil or Civil 3D road reconstruction design can be done in about the same amount of time as new construction design.

In this document, you will begin by exploring the concept of corridor targets. Then by using four examples, the actual process of designing a road reconstruction or rehabilitation will be examined in detail. The examples will outline how to address specific design scenarios and will pass along valuable information about specific functionality within certain subassemblies, as well as specific corridor functionality.

After these specific examples, you will then learn the recommended procedures and techniques to finalize the design by addressing minor design issues and controlling the visibility of components of the design through codes and code sets. Next, you will examine the process of generating cross section data and section views to begin assembling the necessary information for construction documentation. Lastly, this paper will conclude with brief review of the key corridor concept and summarize the theory behind subassemblies.

Introduction to Corridor Targets

Before discussing road rehabilitation and reconstruction specifically, it is important that the key concept of corridor targets is understood. One way of describing a corridor target is that it is a way for the corridor to interact with and respond to other objects in the drawing. Through the subassemblies that are used in the model, corridors have the ability to target surfaces, alignments, profiles, feature lines, polylines, and survey figures. Through this interaction, corridors can be designed to automatically tie embankments to a surface, widen a lane along an alignment, match a ditch invert to a profile, and accommodate many other design scenarios. Generally speaking, targets are used when the geometry of the corridor needs to change as the design progresses along the baseline.

To find out if a given subassembly has targeting capabilities, you can view the Civil or Civil 3D Help for the subassembly and read the section entitled Target Parameters. You can also refer to the Autodesk Whitepaper entitled “[Road Design Basics for AutoCAD Civil and Civil 3D](#)” which contains a table of the subassemblies and their capabilities.

Corridor targets fall into three categories: surface targets; width or offset targets; and elevation or slope targets.

Surface Targets

A *Surface Target* refers to a surface object that the corridor model will react to. For road rehabilitation projects the surface typically models the existing roadway and its surrounding terrain. The most common application of a surface target is found in the daylight subassemblies. The primary function of these subassemblies is to seek out a surface and intersect with it while satisfying certain requirements such as slope, offset or elevation. The simplest daylight subassembly that utilizes a surface target is LinkOffsetOnSurface. This subassembly is typically attached to the

outer edge of a shoulder or the back of a curb. From that point, it will intersect with a surface at a specified offset from the corridor baseline. Since it is tied to an offset location, the slope will vary as it finds each intersection point.

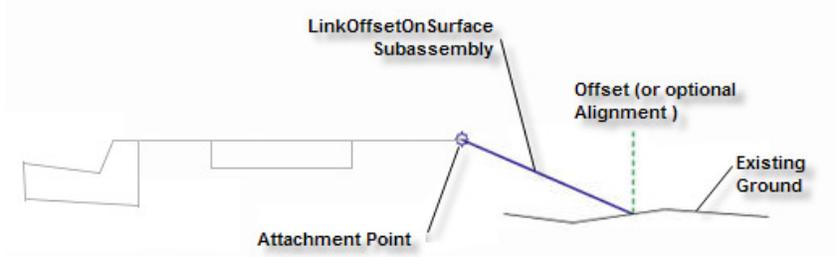


Figure 1: Schematic diagram of the LinkOffsetOnSurface subassembly.

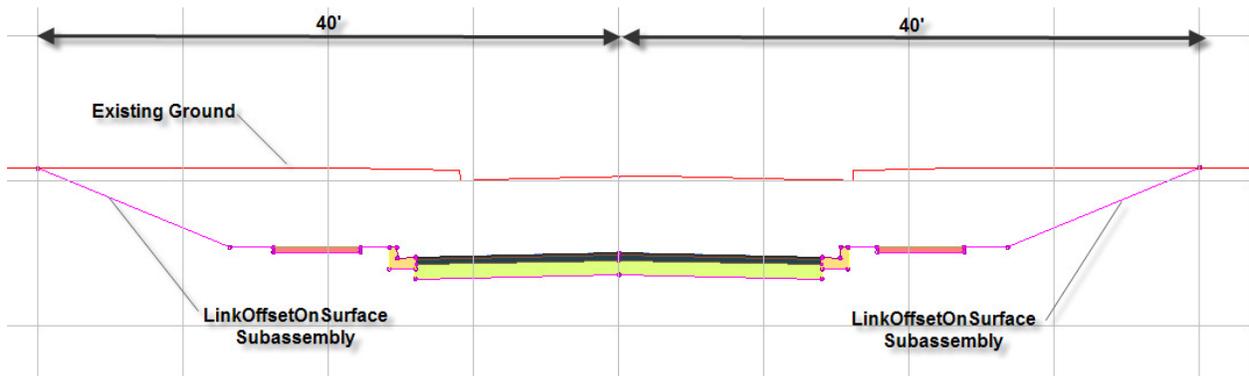


Figure 1A: The LinkOffsetOnSurface Subassembly shown in cross section. In this corridor model, the LinkOffsetOnSurface offset parameter was set to 40'. The cross section shows how the subassembly ties into existing ground 40' from the road centerline, adjusting its slope accordingly.

Another example of a daylight subassembly, LinkSlopeToSurface, can be used in this situation but will hold a given slope. In this way, the offset of the intersection point will vary as the slope is held. Many more daylight subassemblies are available for modeling ditches, benching, different soil materials, and other design components. They have one characteristic in common—they target a surface. There are other subassemblies that target a surface, but not for daylighting purposes. The OverlayWidenMatchSlope1 subassembly, for example, will analyze the surface of an existing road to calculate its cross slope. It does this by sampling the surface at two key points, and calculating the slope between them. The Sample Point tells the subassembly where to make its first reading of the target surface elevation. The insert point takes a second reading of the target surface elevation. The subassembly then calculates the difference between these two elevations to come up with the existing road cross slope. Then, when the additional lanes are added for the new widening, they will use that slope to create a continuous cross slope.

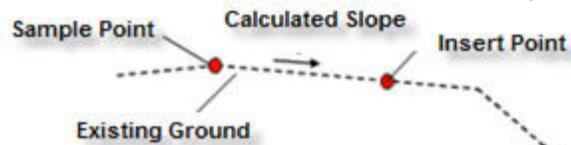


Figure 2A: Civil 3D reads the elevation of the target surface at the Sample Point and Insert Point to determine the existing cross slope.

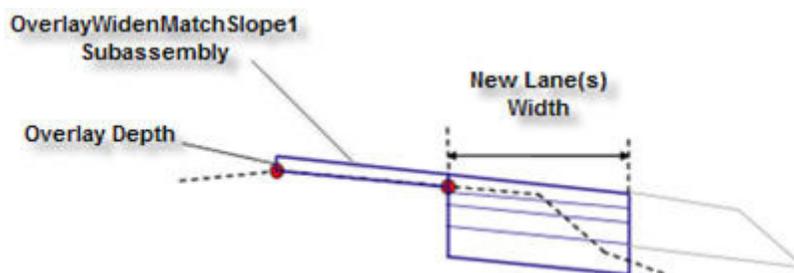


Figure 2B: Once Civil 3D has determined the existing cross slope, the OverlayWidenMatchSlope1 subassembly models an overlay of the existing lane(s) and creates new lane(s) to the design specifications.

The OverlayWidenMatchSlope2 subassembly works similarly to the OverlayWidenMatchSlope1 subassembly, except it builds both sides of the road centerline at once.

Surface targets can also be used for several retaining wall, ditch and trench pipe subassemblies that utilize a surface target to define the geometry of a particular design component.

Width or Offset Targets

A width or offset target is used to define a changing horizontal location of a key point on a subassembly as it relates to the baseline alignment, or another point on the subassembly. The target can be an alignment, feature line, polyline, or survey figure. The most common example of using a width or offset target is when widening a road to provide a turning lane. The OverlayWidenMatchSlope1 subassembly (Figure 2B) has the ability to target an alignment, feature line, polyline, or survey figure to define the Width value. When the target is assigned, the edge of the subassembly becomes “attached” to an object defining its edge and will “widen or narrow” (Figure 3) to maintain that attachment. In addition, the Sample Point and Insert Point in the OverlayWidenMatchSlope1 subassembly can each be assigned a target, controlling the location of these points at specific locations along the corridor.

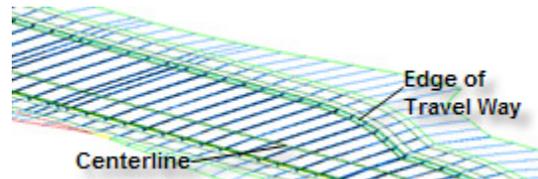


Figure 3 Specific subassemblies can use alignments, profiles, polylines, feature lines, or survey figures as targets to control the shape of the corridor.

Elevation or Slope Targets

An elevation or slope target is used to define a changing vertical location of a key point on a subassembly as it relates to the baseline profile, or another point on the subassembly. An elevation or slope target can be a profile, feature line, 3D polyline, or survey figure. One example of an elevation or slope target is the use of a profile to define the invert elevations of a roadside ditch. In this example, the road and the ditch each follow an individual profile causing the vertical difference between the ditch invert and road centerline to differ as the design progresses along the baseline. In this way, the slope of the ditch can be controlled for drainage purposes while the slope of the road is controlled independently.

Another example of an elevation or slope target can be found in the OverlayCrownBetweenEdges subassembly. In this subassembly the elevations of the Left Edge Point and Right Edge Point can be controlled via an elevation target. This target is commonly a survey figure representing the existing edge of pavement, defined as a result of a topographic route survey performed and processed in the Civil products. Of course, any other suitable elevation target, such as a profile, feature line or 3D polyline could also be used.

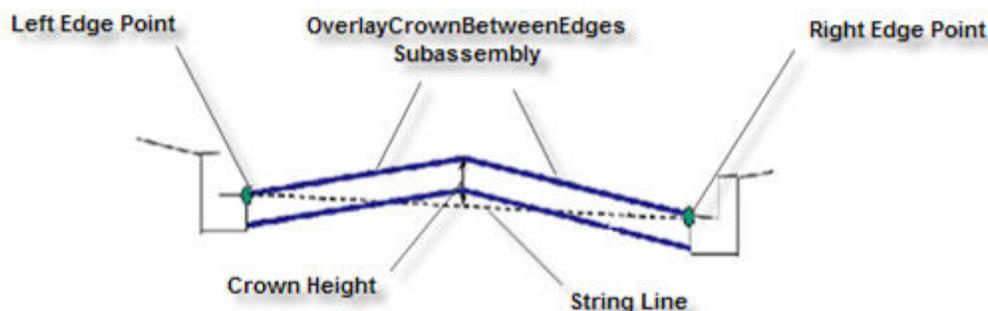


Figure 4: Schematic diagram of the OverlayCrownBetweenEdges subassembly. The Left Edge Point and Right Edge Point can be tied to an elevation target—such as the survey figure of the existing edge of pavement, created as a result of a topographic route survey.

Design Examples

To explore road rehabilitation and reconstruction design with the Civil products, we will examine four common examples. Of course each project is unique, but the concepts that will be discussed can be applied to similar projects. For clarity, here are some definitions of certain terms used in these examples:

- **Milling:** The removal of existing pavement.
- **Leveling:** Fill that is overlaid on the existing or milled surface to reshape its geometry.
- **Overlay:** A new layer of pavement overlaid on some combination of existing, milled, and leveled surfaces.
- **Trim Point:** The outer edge of the area that is being milled, leveled, or overlaid.
- **Sample Point:** An offset at a station where the existing road surface is sampled to determine the current elevation at that point.

Example 1: Mill and Overlay

The first design example is a city street undergoing its first rehabilitation, requiring ruts and mounds to be removed while maintaining the original vertical design of the road. The portion of the street undergoing rehabilitation has no curves and therefore no superelevation. The existing cross slope of the road will be maintained throughout the design. For this design, the key component will be the OverlayMillAndLevel2 subassembly.

The OverlayMillAndLevel2 Subassembly

The OverlayMillAndLevel2 subassembly is designed for rehabilitating a crowned road. It will automatically provide milling or leveling where needed, based on user-defined parameters, by analyzing the existing ground surface at each cross section. The cross slope can be controlled a number of ways; either through superelevation, matching the existing cross slope, or according to a user specified value.

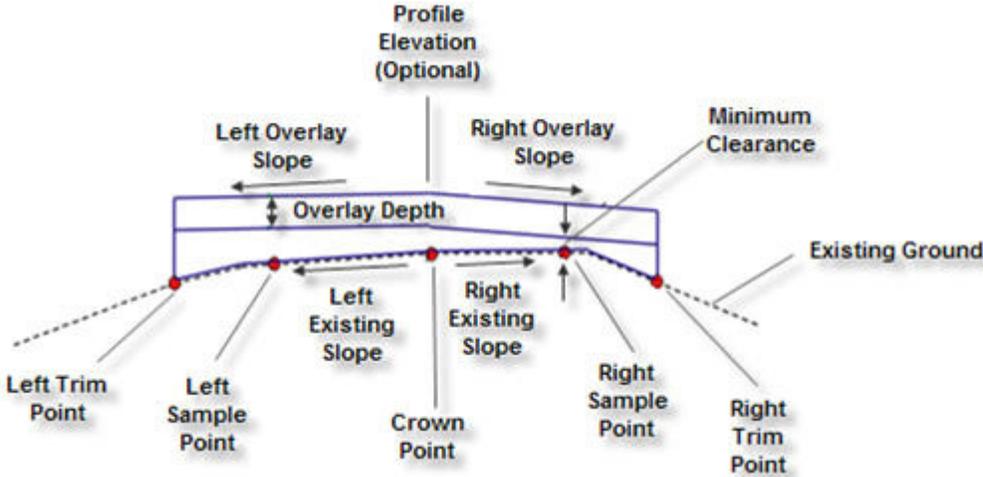


Figure 5A: Schematic diagram showing the behavior of the OverlayMillAndLevel2 subassembly in the first example where leveling is required.

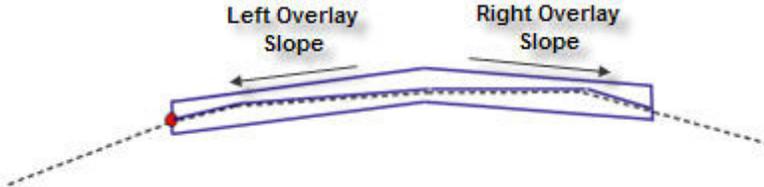


Figure 5B: Schematic diagram showing the behavior of the OverlayMillAndLevel2 subassembly in the second example where milling is required.

In this second example, the intent will be to mill the pavement roughly 1 ½” and provide a 1 ½” overlay to return the road surface to near its original grade. Variations in the existing paved surface will cause the milling depth to vary, thus smoothing out any ruts or mounds. Final elevations will be established by matching the existing cross slope of the road. This will be done by establishing a straight grade between the existing elevation at the centerline and at the edge of the pavement on either side.

Design Steps

1. Define the Baseline Alignment

To begin, define the baseline alignment of the corridor. In this example, the road centerline will serve as the baseline alignment. The geometry of the road centerline can be reconstructed from highway design plans, or from a survey of the existing road.

2. Sample the Existing Ground Centerline Profile

An existing ground surface must exist to perform this step.

3. Define or Identify the Left and Right Edge of Pavement (EOP) Targets

The geometry for these targets can be fixed offsets or feature lines, polylines, or survey figures created from the topographic route survey. Be sure to name the target geometry appropriately. For example, if there is an alignment that follows the edge of pavement along the right side of the road, name the alignment “Right EOP” or something similar that will make it easy to find on a list and assign correctly.

4. Build the Assembly

Begin building the assembly by using the Create Assembly command in the Corridor menu. Insert the OverlayMillAndLevel2 subassembly, assigning the parameters as shown in Figure 6. There are several key parameters to achieve the design intent for this example. Note that the Use Profile option is set to Use Profile. This will help to ensure that the overlay matches the existing ground at the baseline. Also, the Left and Right Overlay Slope Options are both set to Match Slope. This causes the overlay to match the slope calculated between a point on the existing ground at the baseline, and a point on existing ground at the Left and Right Sample Points. In Layout Mode, the Left and Right Sample Point Offsets are set as arbitrary values. At the time the corridor is built, an offset target will set the actual locations of these points.

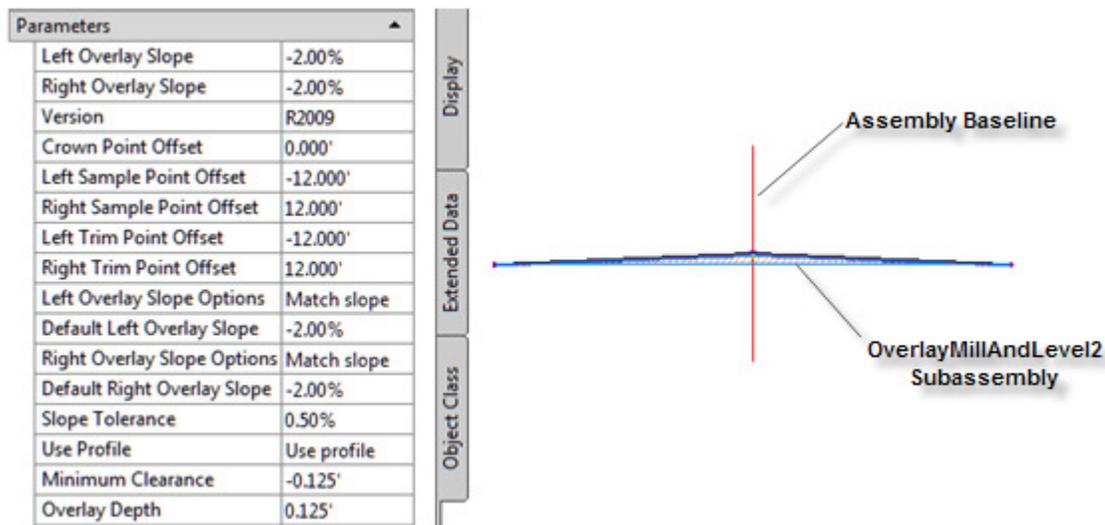


Figure 6: OverlayMillAndLevel2 subassembly shown with recommended parameters for this example.

5. Build the Corridor

Build the corridor using the baseline alignment, the existing ground profile, and the assembly created in the previous step.

6. Assign Targets

Assign the left and right EOP targets to the left and right sample points and trim points of the assembly. Assign the existing ground surface as the surface target.

Target	Object Name	Subassembly
Surfaces	<Click here t...	
Target Surface	Existing G...	OverlayMillAndLevel2
Width or Offset Targets		
Crown Target Alignment	<None>	OverlayMillAndLevel2
Left Sample Target Alignment	Left EOP	OverlayMillAndLevel2
Left Trim Target Alignment	Left EOP	OverlayMillAndLevel2
Right Sample Target Alignment	Right EOP	OverlayMillAndLevel2
Right Trim Target Alignment	Right EOP	OverlayMillAndLevel2
Slope or Elevation Targets		

Figure 7: View of sample and trim point targets for the corridor model.

7. View the Design

View the design using the View/Edit Corridor Sections command in the Corridors menu to check that the intent of the design has been met.

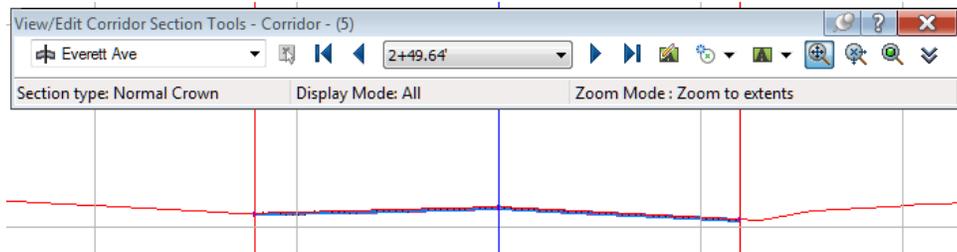


Figure 8: The View/Edit Corridor Sections command.

Results

As you view the design using the View/Edit Corridor Sections command you should see that in most sections, 1.5" of milling has been performed and replaced with 1.5" of overlay (Figure 9). In sections where there are ruts, additional material will be shown where the rut has been filled (Figure 10). In areas with mounds, additional milling will be shown (Figure 11). This has all happened automatically as a result of the parametric capabilities of the OverlayMillAndLevel2 subassembly. At each section, the subassembly analyzes the existing ground cross section to determine the existing cross slope and the location of the bottom of the overlay as per the minimum clearance value. It then automatically determines where material will need to be added or milled away to achieve a constant slope between the existing ground at the baseline and existing ground at the EOP. Using codes along with the ability of the Civil products to compute materials—important information such as the amount of milling, and the quantities of leveling and overlay materials required, can be automatically calculated.

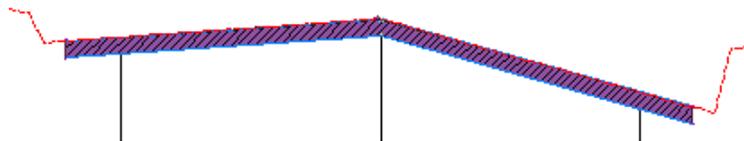


Figure 9: Section showing typical condition. Existing pavement is milled 1.5" (hatched area) then a 1.5" overlay is applied (shaded area).

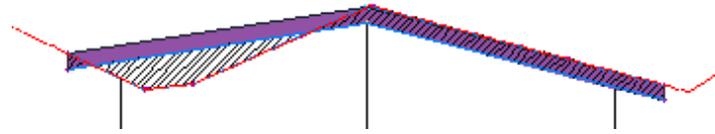


Figure 10: Section showing existing rut. Leveling is required in the rut area on the left.

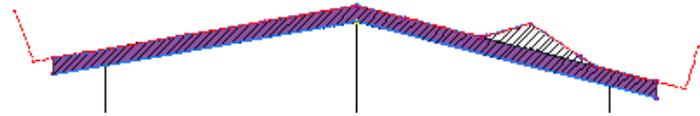


Figure 11: Section showing existing mound. Additional milling is required to remove the mounded area.

Example 2: Three-Inch Minimum Overlay

The second design example is a city street undergoing its second improvement. In this example, a minimum 3-inch overlay is required throughout the design. The key subassembly will once again be OverlayMillAndLevel2

The OverlayMillAndLevel2 Subassembly

For this example, the minimum clearance parameter will be changed to a positive value of 0.125' (1.5") to place the bottom of the overlay above the existing pavement surface. The overlay will be composed of a 1.5" leveling course topped with a 1.5" wearing course. The other key parameter will be the Use Profile option, which in this case will be set to Use Minimum Clearance. The goal in this design is not to match the original vertical design of the road, but instead to provide a minimum 3" overlay, thus raising the profile of the road three inches or more at all locations.

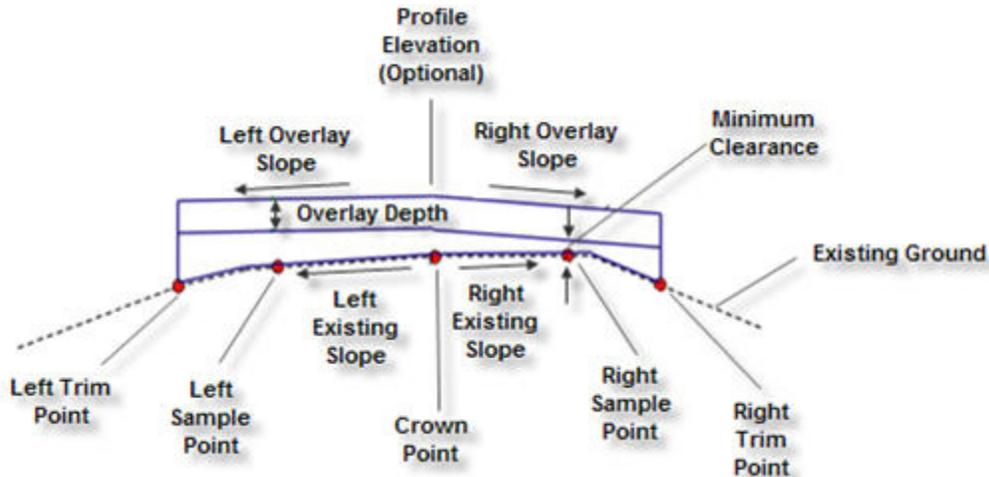


Figure 12A: Schematic diagram showing the behavior of the OverlayMillAndLevel2 subassembly in first example where leveling is required.

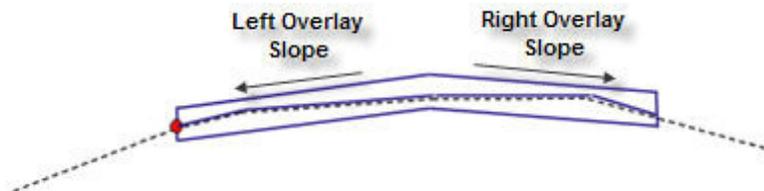


Figure 12B: Schematic diagram showing the behavior of the OverlayMillAndLevel2 subassembly in second example where milling is required.

Design Steps

1. Define the Baseline Alignment

To begin, define the baseline alignment of the corridor. In this example, the road centerline will serve as the baseline alignment. The geometry of the road centerline can be reconstructed from highway design plans, or from a right-of-way survey.

2. Sample the Existing Ground Centerline Profile

An existing ground surface must exist to perform this step.

3. Define or Identify the Left and Right Edge of Pavement (EOP) Targets

The geometry for these targets can be feature lines, polylines, or survey figures generated as a result of the topographic route survey.

4. Build the Assembly

Begin building the assembly by using the Create Assembly command in the Corridor menu. Insert the OverlayMillAndLevel2 subassembly, assigning the parameters as shown in Figure 13. There are several key parameters to achieve the design intent for this example. Note that the Use Profile option is set to Use Minimum Clearance. This will help to ensure that the bottom of the overlay is always at least 0.125' (1.5") above the existing pavement surface. The 1.5" clearance combined with a 1.5" overlay depth will yield a 3" minimum new pavement depth at all points. Also, the Left and Right Overlay Slope Options are both set to Match Slope. This causes the overlay to match the slope calculated between a point on the existing ground at the baseline, and a point on the existing ground at the Left and Right Sample Points. In Layout Mode, the Left and Right Sample Point Offsets are set at an arbitrary value. At the time the corridor is built, an offset target will set the actual locations of these points.

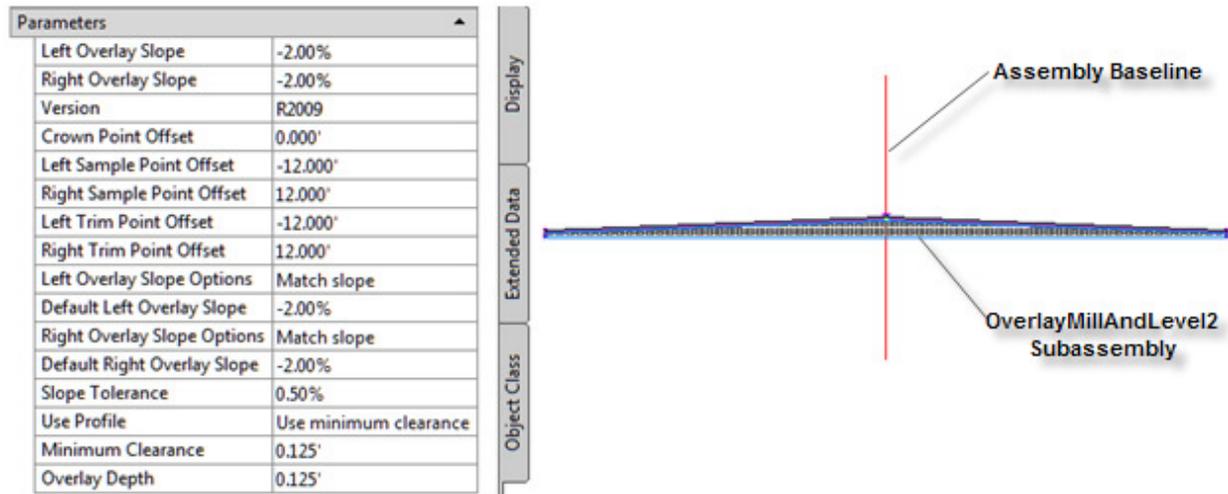


Figure 13: OverlayMillAndLevel2 subassembly shown with recommended parameters for this example.

5. Build the Corridor

Build the corridor using the baseline alignment, the existing ground profile and the assembly created in the previous step.

6. Assign Targets

Assign the left and right EOP targets to the left and right sample points and trim points of the assembly. Assign the existing ground surface as the surface target.

7. View the Design

View the design using the View/Edit Sections command in the Corridors menu to check that the intent of the design has been met.

Results

As you view the design using the View/Edit Sections command you should see that in most sections, 1.5" of leveling has been performed and topped with 1.5" of overlay (Figure 14). In sections where there are ruts, additional material will be shown where the rut has been filled (Figure 15). In areas with mounds, the leveling course will be deeper to accommodate the raised portion of the paved surface while maintaining the minimum 1.5" clearance (Figure 16). This has all happened automatically as a result of the parametric capabilities of the OverlayMillAndLevel2 subassembly. At each section, the subassembly analyzes the existing ground cross section to determine the existing cross slope and the location of the bottom of the overlay as per the minimum clearance value. It then automatically determines the amount of leveling material that will need to be added to achieve a constant slope between the existing ground at the baseline and existing ground at the EOP.

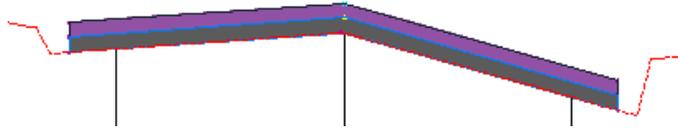


Figure 14: Typical section of road with 1.5" leveling and 1.5" overlay layers.

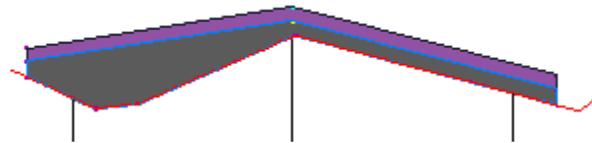


Figure 15: Additional leveling material (left side) required due to an existing rut.

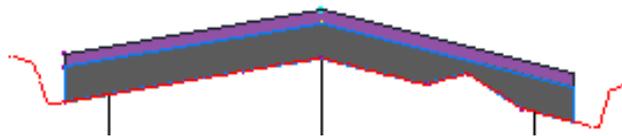


Figure 16: Leveling layer is deeper due to maintaining minimum 1.5" depth above raised area in existing pavement (right side).

Example 3: Superelevated Highway Reconstruction

In this example, an existing highway is exhibiting major deterioration and is overdue for rehabilitation. In addition, the city has been asked to meet AASHTO (American Association of State Highway Transportation Officials) requirements for superelevation, as well as shoulder rollover control. To address these needs, a combination of the OverlayWidenWithSuper1, LaneOutsideSuperWithWidening and ShoulderExtendSubbase subassemblies will be used. Also, in order to tie into the existing storm drainage system, the designer must be able to control ditch elevations independently, which will be handled via the DaylightBasin subassembly.

To meet AASHTO superelevation requirements, a built-in AASHTO design criteria file will be applied to the alignment of existing road. This will assign the appropriate superelevation and transition values based on AASHTO criteria. These values will then be applied to the OverlayWidenWithSuper1 and LaneOutsideSuperWithWidening subassemblies at the time the corridor is built. In addition, widening will be applied to the LaneOutsideSuperWithWidening subassembly as needed according to AASHTO standards. This widening occurs automatically based on the parametric nature of this subassembly—where the width of the lane adjusts based on the radius of the curve.

Users who do not use AASHTO standards should check [AutoCAD Civil 3D Services and Support](#). Many Civil 3D 2009 country kits include superelevation tables and design criteria files. For example, the France Civil 3D Country kit includes files for ARP, Instruction sur les Conditions Techniques d'Aménagement des Autoroutes de Liaison (ICTAAL) and Instruction sur les Conditions Techniques d'Aménagement des Voies Rapides Urbaines (ICTAVRU) and the India Civil 3D Country kit includes design standards for Indian Road Congress (IRC). Additionally, users have the ability to create their own design criteria files based on local standards.

The OverlayWidenWithSuper1 Subassembly

As explained earlier, the OverlayWidenMatchSlope1 subassembly calculates the existing cross slope, and rehabilitates the road using that existing cross slope. The next subassembly, OverlayWidenWithSuper1 behaves in a similar way. It will overlay the existing lane(s) and add new ones if desired. But instead of using the existing cross slope, it uses superelevation parameters.

The OverlayWidenWithSuper1 subassembly is inserted into the assembly at the base point. The location of the control point sets the inside edge of the overlay and the insertion point sets the outside edge. The Width value is set to a positive number if widening is to occur. Note: for this example, the Width value will be set to 0.01 to all but omit the new lane and apply only the widening to the design.

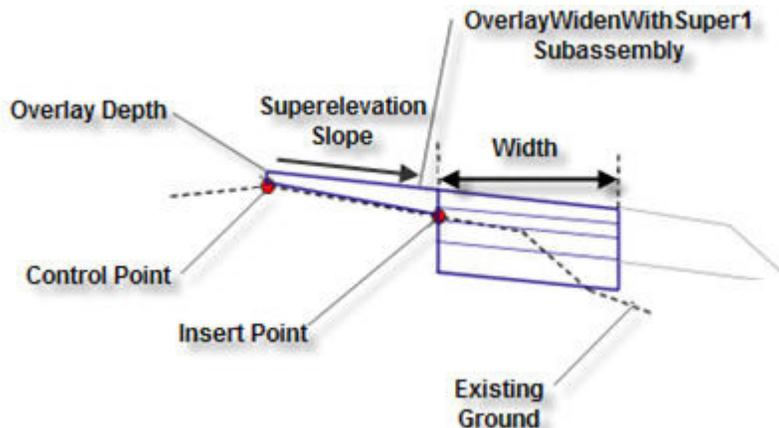


Figure 17: Schematic diagram showing the behavior of the OverlayWidenWithSuper1 subassembly in this example: Non-zero Overlay Depth.

The Overlay Depth is applied at the control point. From the top of the overlay at this location, the superelevation slope is extended outward to form the top surface of the road. The bottom surface of the overlay is created by superimposing links on the existing road surface.

The LaneOutsideSuperWithWidening Subassembly

While the OverlayWidenWithSuper1 subassembly has the ability to add new lanes, it is not as robust as the LaneOutsideSuperWithWidening subassembly. The LaneOutsideSuperWithWidening subassembly is intended for new construction but can be combined, as in this example, with a rehabilitation subassembly to achieve the desired result. The key capability of this subassembly is that it automatically widens when needed based on the radius of the curve. This is accomplished through a formula which considers the number of lanes, radius of the curve, and the length of the wheelbase. Like the previous example, the Width value will be set to 0.01.

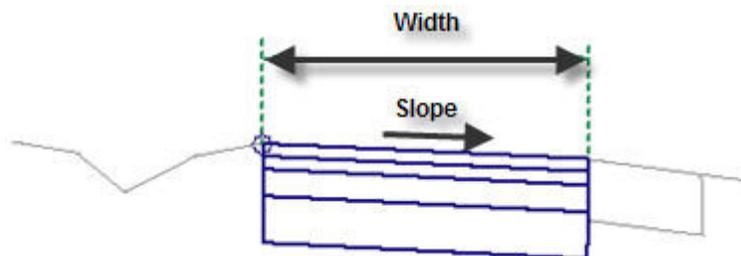


Figure18: Schematic diagram showing the behavior of the LaneOutsideSuperWithWidening subassembly.

The ShoulderExtendSubbase Subassembly

This subassembly is commonly used for new construction. The key functionality of this subassembly is that it obtains its slope value from the superelevation parameters of the baseline alignment. Within the superelevation parameters is the breakover removal option, which reverses the slope of the shoulder to avoid a sharp change in cross slope between the lane and the shoulder. Therefore, by using this subassembly, the shoulder slopes will be corrected in superelevation.

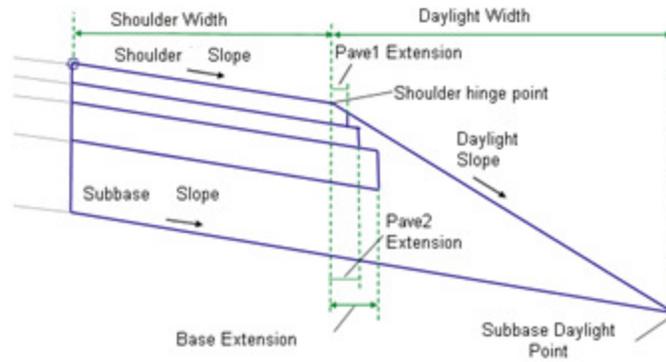


Figure 19: Schematic diagram showing the behavior of the ShoulderExtendSubbase subassembly.

The DaylightBasin Subassembly

This subassembly daylights to a surface but includes a basin or ditch between the road and the daylight point. The geometry of the ditch can be controlled through input parameters, but more importantly for this example, the elevation of the ditch bottom can be controlled by a target parameter. With this capability, the designer will be able to control the elevations of the ditch through a feature line or profile.

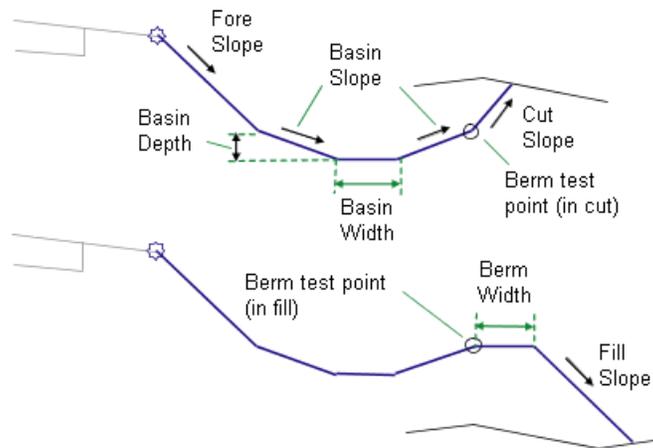


Figure 20: Schematic diagram showing the behavior of the DaylightBasin subassembly.

Design Steps

1. Define the Baseline Alignment

To begin, define the baseline alignment of the corridor. In this example, the road centerline will serve as the baseline alignment. The geometry of the road centerline can be reconstructed from highway design plans, or from a right-of-way survey.

2. Sample the Existing Ground Centerline Profile

An existing ground surface must exist to perform this step. This is typically generated as a result of a topographic route survey of existing conditions.

3. Define or Identify the Left and Right Edge of Pavement (EOP) Targets

The geometry for these targets can be feature lines, polylines, or survey figures generated as a result of the topographic route survey.

4. Define the elevation targets for the ditches.

These targets could be feature lines or profiles representing the elevations of the ditch flowlines.

5. Build the Assembly

Begin building the assembly by using the Create Assembly command in the Corridor menu. Insert the OverlayWidenWithSuper1 and the LaneOutsideSuperWithWidening subassemblies on either side of the assembly baseline, setting the Pave1 and Pave2 depth value to 0.01 for both subassemblies. Adjust other parameters to meet design requirements. Then insert the ShoulderExtendSubbase and DaylightBasin subassemblies. It is useful at this point to change the subassembly names from the default to something more meaningful. In this example, it would make sense to name the OverlayWidenWithSuper1 subassemblies to something like "Overlay – Right" and "Overlay-Left".

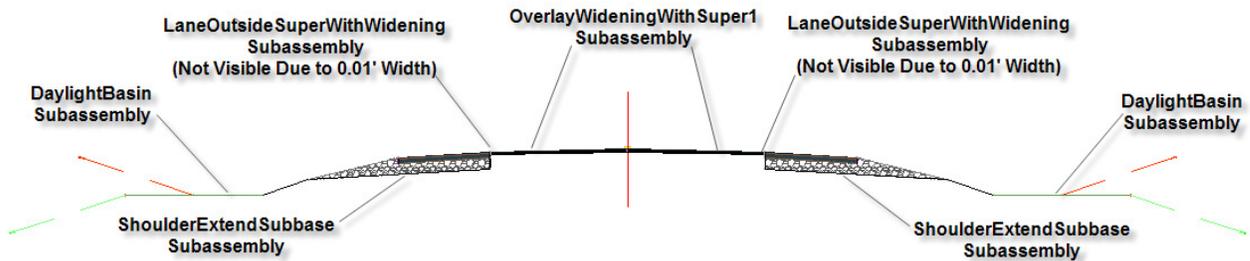


Figure 21: View of the completed assembly.

6. Build the Corridor

Build the corridor using the baseline alignment, the existing ground profile, and the assembly created in the previous step.

7. Assign Targets

Assign the left and right EOP targets to the left and right Insert Point Offsets for the OverlayWidenWithSuper subassembly. Assign the existing ground surface as the surface target for the OverlayWidenWithSuper and DaylightBasin subassemblies. Assign the elevation target (feature line or profile) for the Basin Elevation of the Left and Right DaylightBasin subassemblies. Note that it is easy to locate the proper subassembly because they have been appropriately renamed.

Target	Object Name	Subassembly
Width or Offset Targets		
Control Point Target Alignment	<None>	Overlay-Right
Insert Point Target Alignment	Feature 1	Overlay-Right
Width Target Alignment	<None>	Overlay-Right
Width Alignment	<None>	LaneOutsideSuperWithWidening - (75)
Target Alignment	<None>	ShoulderExtendSubbase - (82)
Control Point Target Alignment	<None>	Overlay-Left
Insert Point Target Alignment	Feature 2	Overlay-Left
Width Target Alignment	<None>	Overlay-Left
Width Alignment	<None>	LaneOutsideSuperWithWidening - (79)
Target Alignment	<None>	ShoulderExtendSubbase - (83)
Slope or Elevation Targets		
Outside Elevation Profile	<None>	LaneOutsideSuperWithWidening - (75)
Target Profile	CL SR544-Left Ditch	DaylightBasin - (109)
Outside Elevation Profile	<None>	LaneOutsideSuperWithWidening - (79)
Target Profile	CL SR544-Right Ditch	DaylightBasin - (108)

Figure 22: View showing target assignments for the overlay and ditch subassemblies. In this example, feature lines are used as targets for the left and right Insert Points and profiles are used to control the ditch elevations.

8. View the Design

View the design using the View/Edit Sections command in the Corridors menu to check that the intent of the design has been met.

Results

As you view the design using the View/Edit Sections command, you should find that sections that are not in superelevation consist of an overlay between the existing edges of pavement, a new shoulder, and the newly designed ditch. The cross slope of the overlay will not be in superelevation, but will match the cross slope values as per the AASHTO design criteria file (or other design criteria you may have specified).

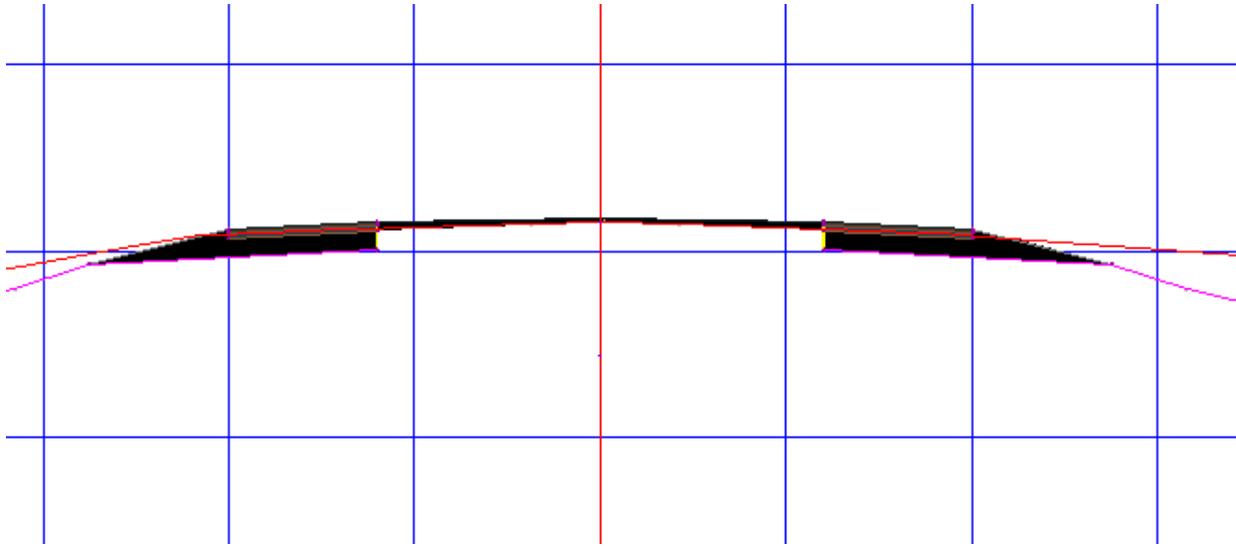


Figure 23: Normal crown section showing overlay and shoulders.

In superelevated sections, the overlay cross slope will be set to match the required superelevation as per AASHTO specifications. The LaneOutsideSuperWithWidening will extend outward due to its parametric widening capabilities and the outside shoulder will reverse its slope due to the breakover removal behavior assigned in the superelevation parameters of the baseline alignment.

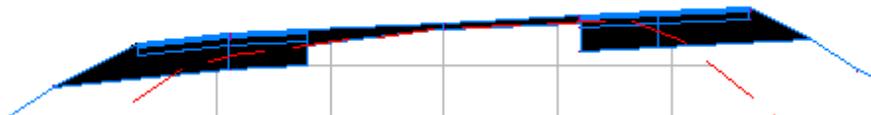


Figure 24: Section showing superelevated overlay and widening along with reversed shoulder slope on outer lane (right side) due to breakover removal.

You should also find that the ditches created via the DaylightBasin subassembly are matching the elevations defined by the basin elevation target that has been assigned.

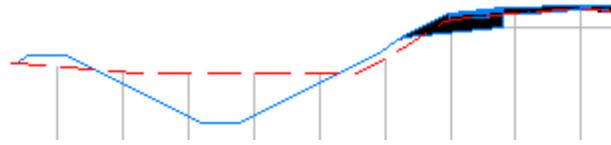


Figure 25: Section view showing ditch created by DaylightBasin subassembly. The flowline elevations of the ditch are set by a target such as a profile or feature line.

Example 4: Overlay and Widening to Create a Turning Lane

In this example, as a part of other road improvements, you are asked to provide a turning lane at a particularly busy intersection. This is in addition to a three-inch overlay that is being applied throughout the improved area of the road. There will be a transition area into the turning lane so the width of the new lane will vary. The opposite side of the road only requires an overlay. The construction of this road includes curb and gutter. The key subassembly in this example will be OverlayWidenMatchSlope1.

The OverlayWidenMatchSlope1 Subassembly

This subassembly will provide an overlay between the Sample Point and Insert Point by matching the cross slope of the existing pavement. Then, to the outside of the overlay, it will provide full pavement structure to a desired width. The Width value can be assigned a target in situations where the width varies. This target can be an alignment, polyline, feature line or survey figure. This subassembly will be combined with BasicCurbAndGutter and BasicSideSlopeCutDitch to complete the design of the turning line, while on the opposite side of the road, the OverlayMillAndLevel1 subassembly will be used.

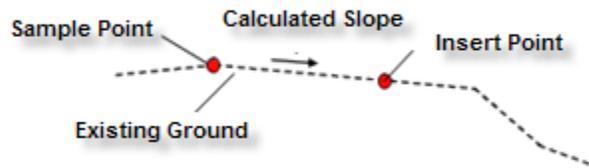


Figure 26A: The Civil products read the elevation of the target surface at the Sample Point and Insert Point to determine the existing cross slope.

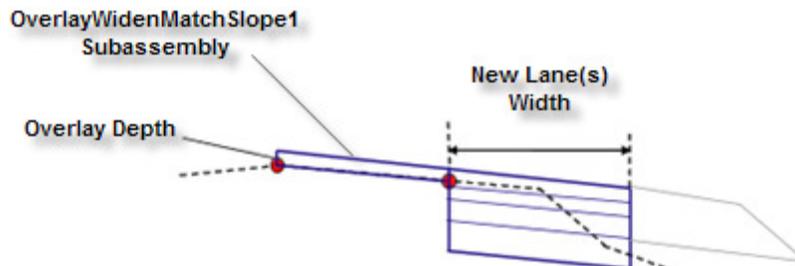


Figure 26B: Schematic diagram showing the behavior of the OverlayWidenMatchSlope1 subassembly.

Design Steps

1. Define the Baseline Alignment

To begin, define the baseline alignment of the corridor. In this example, the road centerline will serve as the baseline alignment. The geometry of the road centerline can be reconstructed from highway design plans, or from a right-of-way survey.

2. Sample the Existing Ground Centerline Profile

An existing ground surface must exist to perform this step.

3. Define or Identify the Existing Edge of Pavement (EOP) Target

The geometry for these targets can be feature lines, polylines, or survey figures generated as a result of the topographic route survey.

4. Define the Edge of Pavement Target for the Turning Lane

This target can be provided as an alignment, polyline, or feature line.

5. Build the Assembly

Begin building the assembly by using the Create Assembly command in the Corridor menu. Insert the OverlayWidenMatchSlope subassembly using arbitrary values for the Sample Point Offset and Width. These values will be assigned by the targets at the time the corridor is built. Complete this side of the assembly by inserting a curb subassembly such as BasicCurbAndGutter and a daylight subassembly such as BasicSideSlopeCutDitch. On the opposite side of the road, if an overlay is the only requirement, a subassembly such as OverlayMillAndLevel1 can be used.

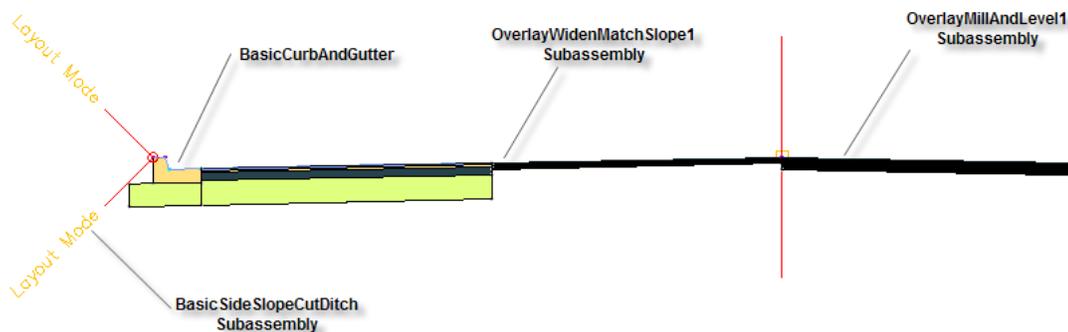


Figure 27: View of the completed assembly showing overlay and widening on the left side and overlay on the right side.

6. Build the Corridor

Build the corridor using the baseline alignment, the existing ground profile, and the assembly created in the previous step.

7. Assign Targets

Assign the left and right EOP targets to the Insert Point Offsets for the OverlayWidenMatchSlope1 and OverlayMillAndLevel1 subassemblies. Assign the existing ground surface as the surface target for the OverlayWidenMatchSlope1, OverlayMillAndLevel1, and BasicSideslopeCutDitch subassemblies. Assign the target to the Width value for the OverlayWidenMatchSlope1 subassembly to establish the EOP of the turning lane.

Target	Object Na...	Subassembly
Surfaces	<Click here ...>	
Existing Surface	EG - SR544	OverlayWidenMatchSlope1 - (135)
Target Surface	EG - SR544	BasicSideSlopeCutDitch - (153)
Target Surface	EG - SR544	OverlayMillAndLevel1 - (144)
Width or Offset Targets		
Insert Point	Feature 2	OverlayWidenMatchSlope1 - (135)
Sample Point	<None>	OverlayWidenMatchSlope1 - (135)
Width	Polyline- 1	OverlayWidenMatchSlope1 - (135)
Inside Sample Target Alignment	<None>	OverlayMillAndLevel1 - (144)
Inside Trim Target Alignment	<None>	OverlayMillAndLevel1 - (144)
Outside Sample Target Align...	EOP-R	OverlayMillAndLevel1 - (144)
Outside Trim Target Alignment	EOP-R	OverlayMillAndLevel1 - (144)
Slope or Elevation Targets		

Figure 28: View showing target assignments for the subassemblies used in this design. In this example, a polyline is used as the offset target controlling the outer edge of the turning lane.

8. View the Design

View the design using the View/Edit Sections command in the Corridors menu to check that the intent of the design has been met.

Results

As you view the design, you should see an overlay of the existing road between the centerline and existing edge of pavement. The cross slope of the overlay should match that of the existing road. Outside the overlay should be a newly constructed lane with a cross slope that matches the overlay. The new shoulder and daylighting complete the design on this side. The opposite side will consist of only an overlay which matches the existing cross slope of the road.

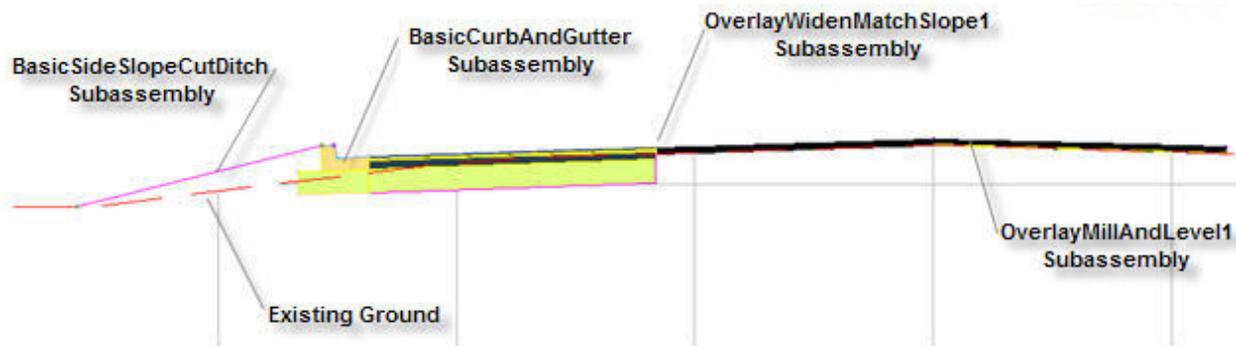


Figure 29: Section view showing overlay and widening (left side) and overlay (right side).

In the transition area, as the road widens to create the new turning lane, the section will be similar but with a narrower widening region.

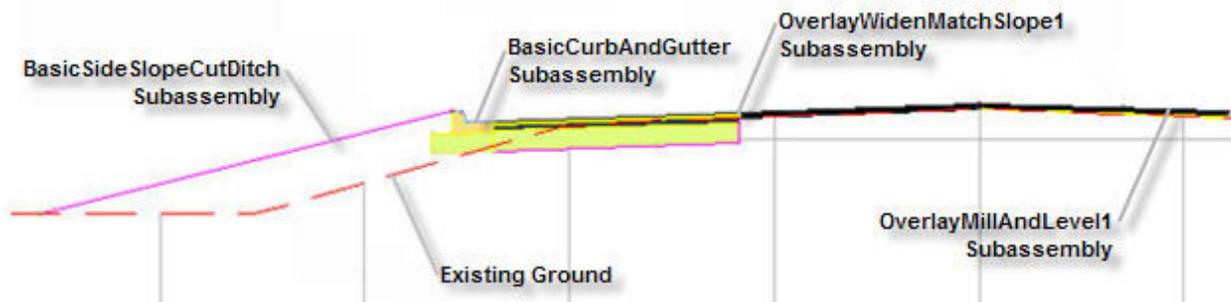


Figure 30: Section view showing overlay and widening in transition area. Note the narrower widened area compared to Figure 29.

Finalizing the Design

For any design scenario, once the corridor is built (as described in the examples above), there is usually some additional work required to address minor design issues and to yield additional information from the design. The most common of these are listed and described below.

Using View/Edit Corridor Sections to View the Design

As you saw in all of the design examples, the View/Edit Corridor Sections command is a vital tool in viewing the design. The main advantage of this tool is that it allows you to view the design from a cross section perspective without actually creating cross section views in the drawing. You can also make individual edits to each section by changing subassembly parameters on a section-by-section basis and having the entire corridor update automatically.

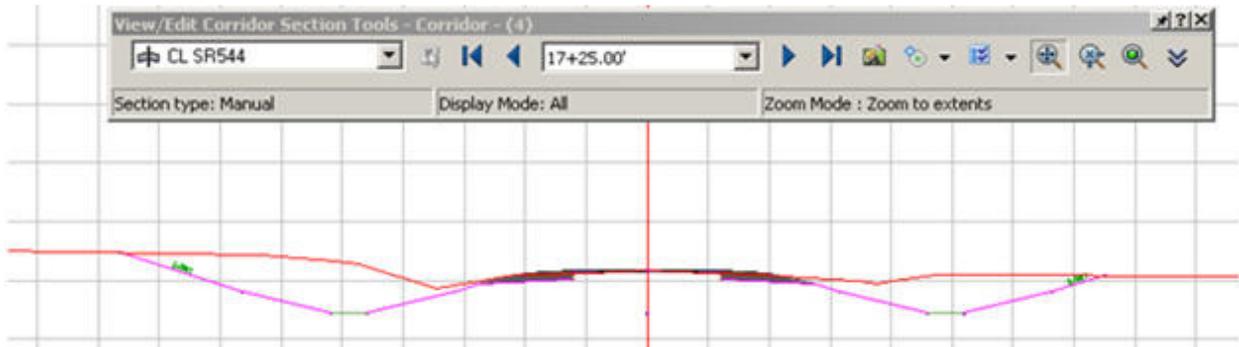


Figure 31: The View/Edit Corridor Sections command.

Additional Corridor Sections

When the corridor is initially built, the corridor section interval is usually based on default values. Often, key transition points occur between the corridor sections causing irregularities in the geometry as shown in Figure 32.

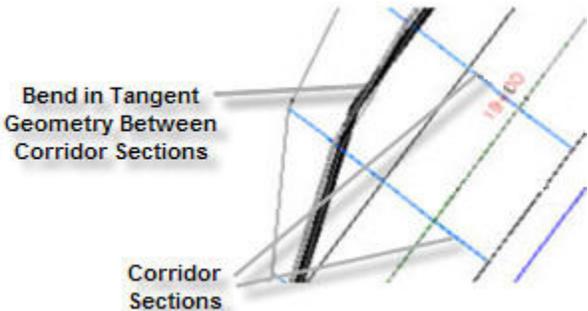


Figure 32: Plan view of corridor showing improper construction of the corridor due to a bend in an offset target occurring between corridor sections.

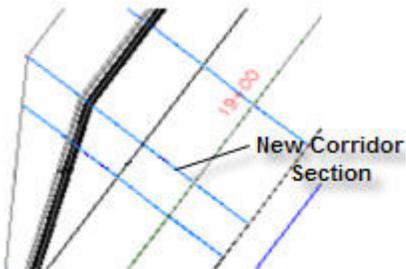


Figure 33: Add or modify assembly frequencies using Frequency to Apply Assemblies, which can be accessed in the Corridor Properties Dialog.

This situation can be easily corrected by accessing the Properties of the corridor and creating an additional section through the Frequency settings. The Frequency settings allow you to add individual stations by selecting precise points in the drawing. In Figure 33, you see an additional corridor section added by selecting the bend in the target polyline. Note how the corridor geometry properly follows the target geometry.

Profile Smoothing

The milling, overlay, and widening subassemblies described in the examples above analyze the existing roadway surface on a station-by-station basis to derive the final design cross sections. This helps to achieve the optimum design at each individual station based on your parameters, but it can also result in an uneven or bumpy profile when you look at the corridor model longitudinally.

This can be addressed by using two or more design iterations. For example, let's look at Example 1 above. In the initial design pass we set the parameters so that the assembly is built based on the existing road elevation at the centerline. To develop the final design you would follow these steps:

1. Use the resulting corridor surface to build a "proposed" profile.
2. Display that profile in a Profile View and edit the profile to help ensure smoothness and compliance with safety standards.
3. Edit the corridor model, reset the parameters of OverlayMillAndLevel2 to use the modified profile, and rebuild the corridor.
4. Examine the results to check that the rehabilitation criteria are still being met. If not, modify the profile or the subassembly parameters, iterating until you have achieved the desired outcome both cross-sectionally and longitudinally.

Leveraging Code Set Styles

Code set styles can be used to provide labeling and control the appearance of the corridor components as they are seen in cross section view. Through effective application of codes and code set styles, you can help make the design easier to analyze and more visually appealing. Code set styles can be applied to the corridor, assemblies, corridor sections in cross section views, and corridor sections shown with the View/Edit Corridor Sections command. Code sets can also be applied to add plan view hatching or render materials to the corridor. As seen in the images below, much information can be shown by simply applying a well-built code set style. This information displays automatically and does not require additional effort by the designer, once the code set is in place.

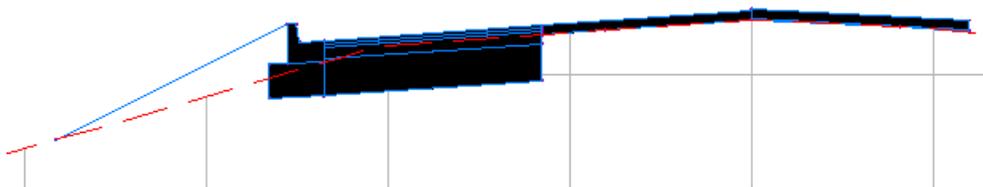


Figure 35: Section view using a Basic code set style.

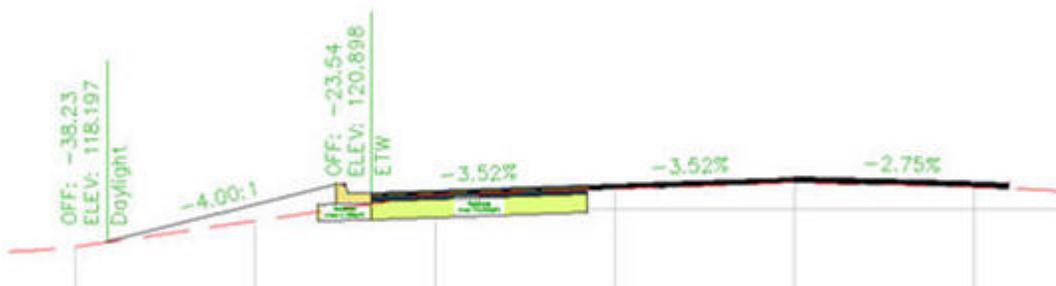


Figure 36: Same section view using a customized code set style. Note the labels as well as the differentiation between materials.

Creating Section Views

Often, the final step in finalizing the design is creating cross section views. Depending on the length of the design and the required interval for providing section views, this task can generate dozens of cross section sheets in the final sheet set. Section View styles can be customized to show a variety of labeling, including section volume tables that update every time the corridor is rebuilt. Fortunately, with the corridor model and supporting data in place, creating section views is a simple three-step process.

Step One: Create Sample Lines

Sample lines are the lines along which the Civil products will cut sections through the corridor, surfaces, and even pipe networks so that the information can be shown in section views. To begin, launch the Create Sample Lines command in the Sections menu then select the baseline alignment for the corridor. The Sample Line Tools toolbar will appear providing various commands for generating sample lines. Typically, sample lines are generated using *By range of stations* as shown in Figure 37. This command will generate multiple sample lines along given intervals. While executing this command, you will be able to control the interval along curves, tangents, and spirals separately. You will also be able to specify the width of the left and right swath and the addition of sections at critical superelevation stations as well as other variables.

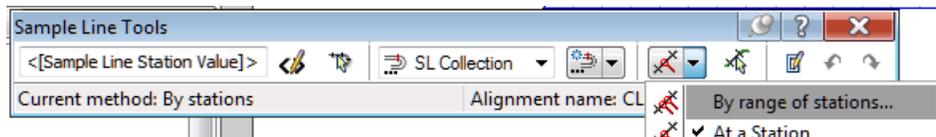


Figure 37: By range of stations command being utilized on the Sample Line Tools toolbar.

Step Two: Configure the Group Plot Style

If your intent is to plot cross section sheets, you will want to set up a Group Plot Style that matches the sheet size and title block that you will be using. The group plot style will apply the settings that you specify for the arrangement and spacing of the section views within the plot area that you have indicated. This will allow the Civil products to automatically group the section views into sheet arrangements making it easier to display and plot the section views within your company title block.

Step Three: Create the Section Views

Once the sample lines and group plot style are in place and properly configured, you can launch the Create Multiple Section Views command within the Sections menu. Be sure to apply the group plot style that you have configured.

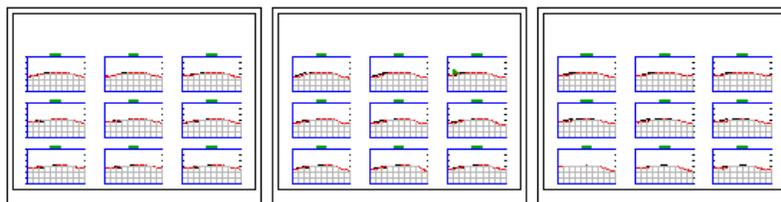


Figure 38: Section views plotted using a group plot style.

Conclusion

The goal of this white paper was to illustrate how AutoCAD Civil 2009 and AutoCAD Civil 3D 2009 can be used for road reconstruction and rehabilitation design by explaining key concepts and providing real-world examples. The Civil products leverages corridor targets to help produce a more efficient and dynamic design. Utilizing targets allows the corridor model to interact with other information in the model such as surfaces, alignments, profiles, and feature lines—creating a design that is able to merge into its surroundings and react dynamically when those surroundings change. Intelligent features such as subassemblies used in conjunction with surface targets helps you to analyze an existing road and helps you to match its cross slope efficiently—thus aiding in reducing the time the same task would take if performed manually. Similarly, offset and elevation targets can be utilized to automatically create turning lanes, control the elevations of ditches, and define the limits of an overlay, instead of manually editing these values, section-by-section. AutoCAD Civil and Civil 3D also include a variety of commands and procedures that aid in finalizing the design—allowing you to put the finishing touches on the design and generate high-quality construction documents.

Road rehabilitation and reconstruction design is arguably the most challenging type of road design. The use of the AutoCAD Civil and Civil 3D software helps simplify these types of designs—aiding you in completing them in less time and with greater accuracy, as well as helping you to boost your productivity while promoting the improvement of quality in your designs.

Note: If you would like to find out more information about specific subassemblies you can refer to the Autodesk Whitepaper entitled “[Road Design Basics with AutoCAD Civil and Civil 3D](#)”, which contains a table listing all subassemblies and their targeting and parametric abilities.

About the Author

Engineered Efficiency, Inc. is a CAD consultancy and software vendor that has been involved in the testing, training, and implementation of AutoCAD Civil 3D since its initial release in 2003. EE has worked with end-users across North America to successfully implement Civil 3D and regularly presents at Autodesk University. EE has authored several works on Civil 3D, including *Mastering AutoCAD Civil 3D 2009*; AOTC Civil 3D *Solution Series* courseware including *Residential Grading, Designing Intersections and Cul-de-Sacs*, and *Creating and Managing Plan Sets*; and several AutoCAD Civil 3D whitepapers. Engineered Efficiency, Inc. can be reached online at www.eng-eff.com.

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