

# Road Rehabilitation and Reconstruction Using 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 often requires an individual design, with special attention to cross slopes, pavement irregularities, and many other potential conditions. Despite these challenges, the designer is required to produce an accurate account of the required material types and quantities. This white paper can help you obtain the technical foundation needed to perform various types of road rehabilitation and reconstruction design with the help of AutoCAD® Civil 3D® software.

In this document, we will begin by exploring the concept of corridor targets. AutoCAD Civil 3D comes equipped with subassemblies designed specifically for road rehabilitation and reconstruction design, as well as the capability to customize subassemblies using Subassembly Composer.

What makes subassemblies more uniquely suited for rehabilitation and reconstruction projects is their ability to interact with and analyze existing conditions, and respond in ways that better 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 Civil 3D, road reconstruction design can be done in about the same amount of time as new construction design.

In this white paper, we use five examples to examine the process of designing a road reconstruction or rehabilitation project, outlining how to address specific design scenarios and passing along valuable information about specific functionality within certain subassemblies, the need and ability to create custom subassemblies, as well as corridor functionality. After these examples, you will learn a few recommended procedures and techniques to help finalize the design, address some minor design issues, and control the visibility of design components through codes and code sets. Next, we will examine the process of generating cross-section data and section views to begin assembling the necessary information for construction documentation. This paper will conclude with a brief review of the key corridor concepts and summarize the theory behind subassemblies.

## Introduction to Corridor Targets

Before discussing road rehabilitation and reconstruction specifically, it is important to understand the key concept of corridor targets. 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 parameters, corridors have the ability to target surfaces, alignments, profiles, feature lines, pipe networks, polylines, and survey figures. 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 information about the targeting capabilities of a subassembly, you can select it in the Subassembly Reference topic of the AutoCAD Civil 3D Help and read the section entitled Target Parameters. The capabilities and parameter tables of each subassembly can be accessed through the contextual user interface when the subassembly object is selected.

Corridor targets fall into three basic categories: surface targets; width and offset targets; and elevation or slope targets. Civil 3D also provides for conditional subassemblies, which automatically add specified subassemblies with defined targets to an assembly when specified vertical or horizontal conditions are encountered along the corridor.

## 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 considering certain requirements, such as slope, offset, or elevation. One of the simplest daylight subassemblies that utilizes a surface target is **LinkOffsetOnSurface**. This subassembly is typically attached to the outer edge of a shoulder. 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.

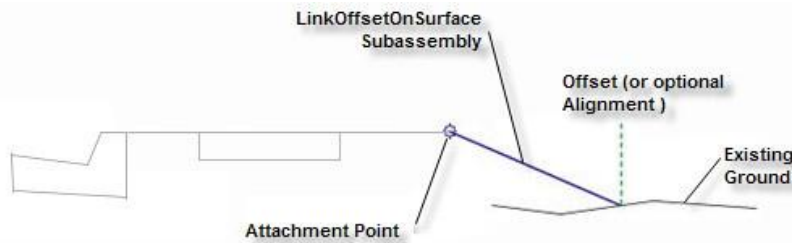


Figure 1: Schematic diagram of the LinkOffsetOnSurface subassembly.

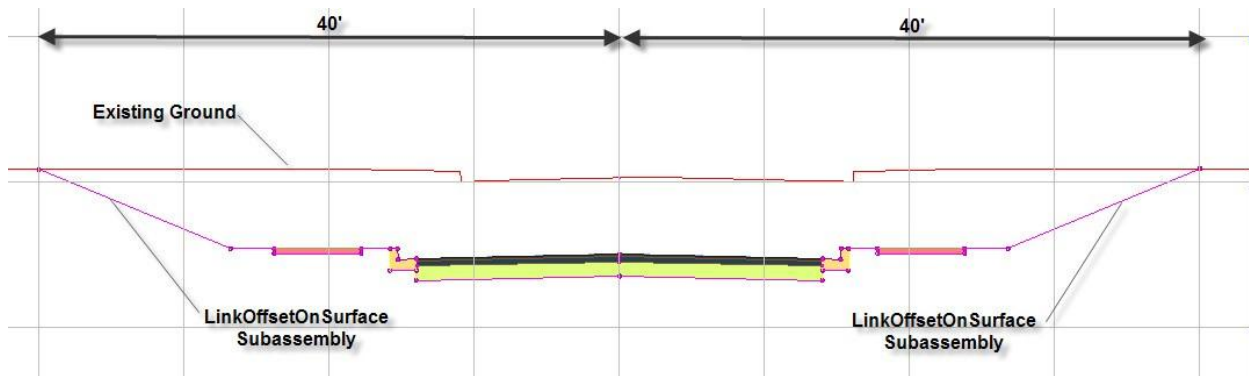


Figure 1A: The LinkOffsetOnSurface subassembly shown in cross section. In this corridor model, the LinkOffsetOnSurface offset parameter was set to 40'. The cross section shows how the subassembly ties into existing ground 40' from the road centerline, adjusting its slope accordingly.

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.

Rehabilitation and reconstruction projects require the use of subassemblies that target a surface, but not for daylighting purposes. The **OverlayWidenMatchSlope1** subassembly, for example, will analyze the surface of an existing road to help 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. When the additional lanes are added for the new widening, they will use this slope to create a continuous cross slope.

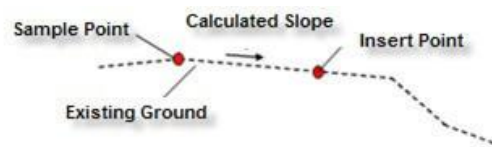


Figure 2A: Civil 3D reads the elevation of the target surface at the Sample Point and Insert Point to help determine the existing cross slope.

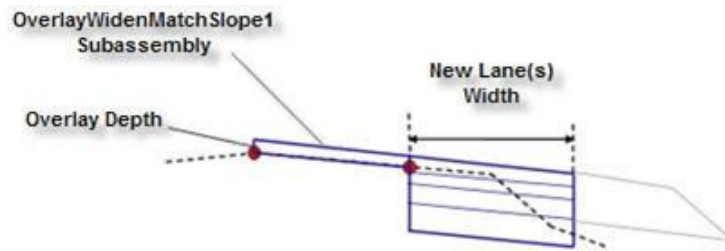


Figure 2B: Once Civil 3D has determined the existing cross slope, the **OverlayWidenMatchSlope1** subassembly models an overlay of the existing lane(s) and creates new lane(s) to the design specifications.

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

## Width and Offset Targets

*Width and offset targets* are used to define a changing horizontal location of a key point on a subassembly; the offset target as it relates to the baseline alignment, and a width target as it relates to another point on the subassembly. The most common example of using an assembly with both a width and an offset target is widening a road in order to help meet current standards. The **OverlayWidenMatchSlope1** subassembly (Figure 2B) has the ability to target an alignment, feature line, polyline, or survey figure to define the width value of the new roadway. When the lane width target, such as the Edge of Travel Way, is assigned, the edge of the subassembly becomes attached to the target object and will widen or narrow (Figure 3) to maintain that match to that location. In addition, the sample point and insert point in the **OverlayWidenMatchSlope1** subassembly can each be assigned an offset target, thus controlling the location of these points at specific locations along the corridor.

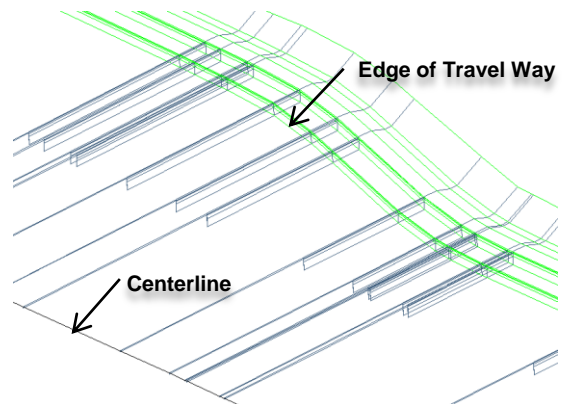


Figure 3: Specific subassemblies can use alignments, profiles, polylines, feature lines, or survey figures as targets to control the shape of the corridor.

## 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 using an elevation or slope target is the use of a profile to define the invert elevations of a roadside ditch, where 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 using an elevation or slope target can be found when the **OverlayCrownBetweenEdges** subassembly is used (Figure 4). By using 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 processed in Civil 3D using the tools provided in the Survey Toolspace and Survey tab. Of course, any other suitable elevation target, such as a profile, feature line, or 3D polyline could also be used.

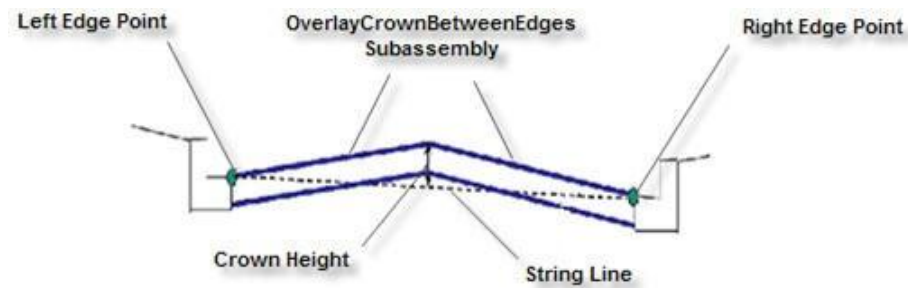


Figure 4: Schematic diagram of the OverlayCrownBetweenEdges subassembly. The Left Edge Point and Right Edge Point can be tied to an elevation target—such as the survey figure of the existing edge of pavement.

## Conditional Subassemblies

*Conditional subassemblies* are special types of subassemblies that provide a means of conditional target control. They automatically add specified subassemblies to an assembly when certain conditions, which you specify, exist. One example is the **ConditionalCutOrFill** subassembly (Figure 5). It can be used to analyze the station, offset, and elevation position of the subassembly, based on the parameters you specify, and then automatically apply different subassemblies, such as daylighting, ditching, and retaining walls, based on whether the subassembly is in a cut or fill condition.

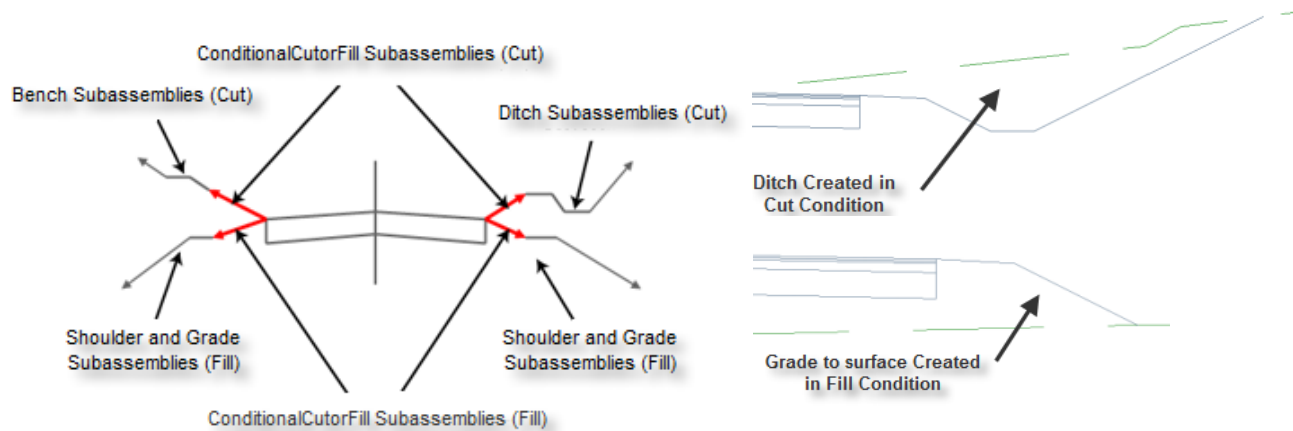


Figure 5: Schematic diagram of a ConditionalCutOrFill subassembly. This shows a configuration to automatically add a bench subassembly on the left and a ditch on the right when Civil 3D detects that the assembly is in a cut condition, and automatically add a shoulder and grade to either side when a fill condition is detected.

The other type of conditional subassembly is the **ConditionalHorizontalTarget** subassembly (Figure 6). This subassembly performs analysis at each station in order to help determine whether an offset target exists within a specified distance and automatically adds various subassemblies, such as widening, curb and gutter, ditching, or daylighting, to an assembly at the corridor station where it deems appropriate. The **ConditionalHorizontalTarget** has the ability to target an alignment, feature line, polyline, or survey figure. A common use for this assembly would be to define where the curb cuts occur for driveways along a road with a curb and gutter, and apply the appropriate changes to each corridor station.

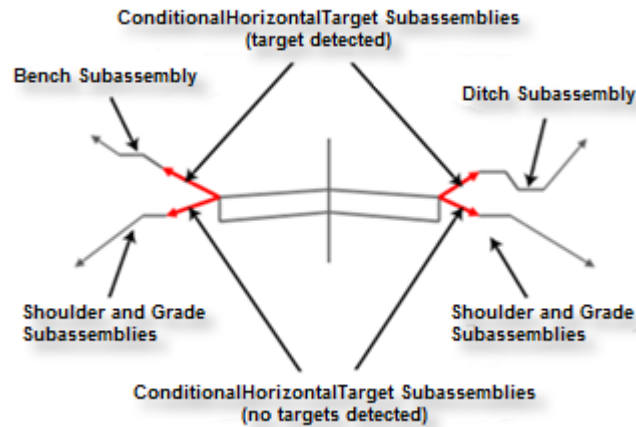


Figure 6: Schematic diagram of a ConditionalHorizontalTarget subassembly. This shows a configuration to automatically add a bench subassembly on the left when an offset target is detected for the left assembly and a ditch on the right when an offset target for the right is detected. When no offset target is detected for either assembly, a shoulder and grade is added.

## Design Examples

To explore road rehabilitation and reconstruction design with AutoCAD Civil 3D software, we will examine five common examples. Of course, each project is unique, but the concepts discussed can be applied to similar projects. For clarity, here are definitions of some terms used in these examples:

- **Milling:** The removal of existing asphalt or bituminous pavement.
- **Leveling:** Pavement 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:** A point on the baseline or offset where the existing road surface is sampled to determine the current elevation at that point.
- **Insert Point:** An offset from the baseline where the existing road surface is sampled to determine the current elevation at that point and define the location where the widening is to occur.

### 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 has no superelevation. The existing cross slope of the road will be maintained throughout the design.

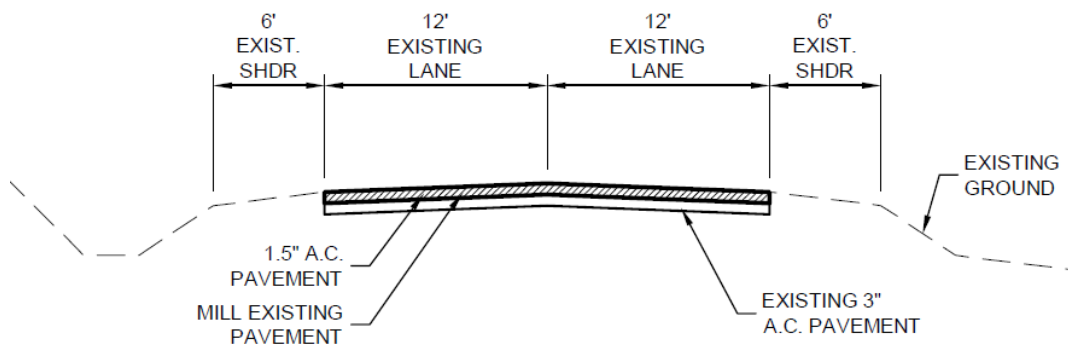


Figure 7: Typical Section

As shown in the Typical Section (Figure 7), the intent will be to mill the pavement roughly 1.5" and provide a 1.5" asphalt 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.

### The OverlayMillAndLevel2 Subassembly

The **OverlayMillAndLevel2** subassembly will be used because it is designed for rehabilitating a crowned road. The subassembly can automatically provide milling or leveling where needed, based on user-defined parameters. This is done by analyzing the existing ground surface at each defined corridor frequency. The cross slope can be controlled a number of ways; either through superelevation, matching the existing cross slope, or applying a user-specified value.

### 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. Create an Existing Ground Surface Profile of the Baseline Alignment

A profile must exist for the subassembly to attach to. 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. In this example, the intention is to use the existing ground surface along the horizontal alignment to define the top of the overlay at the baseline.

#### 3. Define or Identify the Left and Right Existing 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 depicting the existing edge of pavement. 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. If your target alignment was created as an offset alignment, using the default "Offsets name template" will help with the alignment naming convention.

#### 4. Build the Assembly

Begin building the assembly by using the Create Assembly command under Assembly in the Create Design section of the Home tab. Insert the **OverlayMillAndLevel2** subassembly, assigning the parameters as shown in Figure 8. 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 check 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 that are not ultimately used in this example. At the time the corridor is built, the defined offset target will be used to set the actual locations of these points.

#### 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.

| Parameters                      |             |
|---------------------------------|-------------|
| Left Overlay Slope              | -2.000%     |
| Right Overlay Slope             | -2.000%     |
| Version                         | R2013       |
| Superelevation Axis of Rotation | Unsupported |
| Crown Point Offset              | 0.0000'     |
| Left Sample Point Offset        | -12.0000'   |
| Right Sample Point Offset       | 0.0000'     |
| Left Trim Point Offset          | -12.0000'   |
| Right Trim Point Offset         | 12.0000'    |
| Left Overlay Slope Options      | Match slope |
| Default Left Overlay Slope      | -2.000%     |
| Right Overlay Slope Options     | Match slope |
| Default Right Overlay Slope     | -2.000%     |
| Slope Tolerance                 | 0.500%      |
| Use Profile                     | Use profile |
| Minimum Clearance               | -0.1250'    |
| Overlay Depth                   | 0.1250'     |

Figure 8: The recommended OverlayMillAndLevel2 subassembly parameters for this example.



| 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 9: View of sample and trim point targets for the corridor model.

## 7. View the Design

Use the Section Editor to check that the intent of the design has been met.

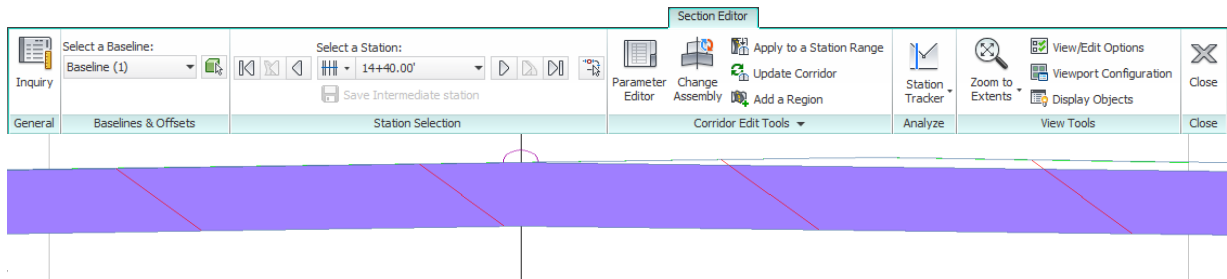


Figure 10: The Corridor Section Editor not only enables you to view each section of the corridor, but is also a robust assembly, subassembly, and corridor changing, modifying, and editing tool.

## Results

As you examine the results using the Section Editor you should see that in most sections, 1.5" of pavement has simply been milled and replaced with 1.5" of asphalt overlay (Figure 11). In sections where there are ruts, additional material will be shown where the rut has been filled (Figure 12). In areas with mounds, additional milling will be shown (Figure 13). This has all happened automatically as a result of the parametric nature 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. You can use the QTO Manager to define and assign pay item materials to codes, and the Takeoff command to compute quantity takeoffs of the pay item assigned to points and links within the corridor. In this way, important information such as the amount of milling and the quantities of leveling and overlay materials required can be automatically calculated.

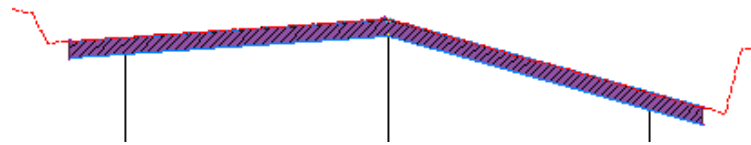


Figure 11: Section showing typical condition. Existing pavement is milled 1.5" (hatched area) then a 1.5" overlay is applied. (shaded area).

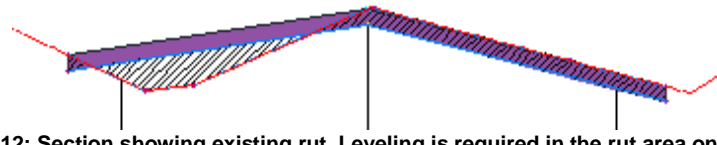


Figure 12: Section showing existing rut. Leveling is required in the rut area on the left.

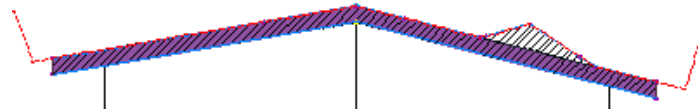


Figure 13: Section showing existing mound. Additional milling is required to remove the mounded area.

## Example 2: Three-Inch Minimum Overlay

The second design example is a city street undergoing its second improvement. In this example, a minimum 3" overlay is required throughout the design.

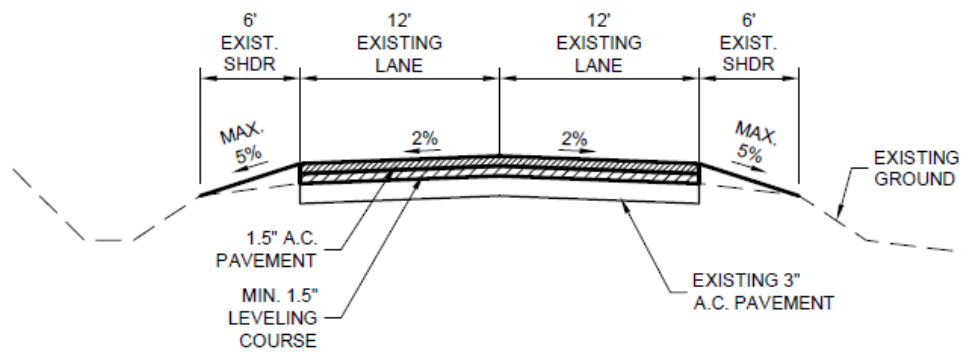


Figure 14: Typical Section

As shown in the Typical Section (Figure 14), the overlay will be composed of a 1.5" leveling course topped with a 1.5" wearing course. The road cross-section grades will be set at two percent while maintaining a minimum overlay depth of 3.0" above the existing road section.

### The OverlayMillAndLevel2 Subassembly

The **OverlayMillAndLevel2** subassembly will automatically detect a defined minimum overlay depth while maintaining user-defined cross-slope parameters and apply leveling where needed for a crowned road. 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 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 3" or more at all locations.

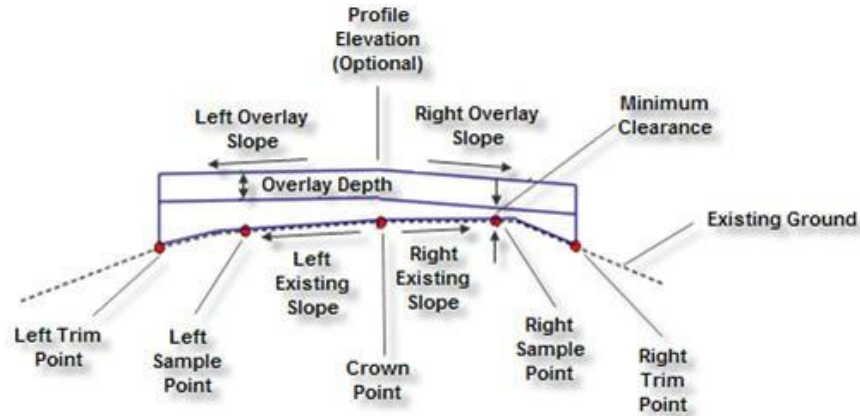


Figure 14A: Schematic diagram showing the behavior of the OverlayMillAndLevel2 subassembly in first example where leveling is required.

## 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. Create an existing Ground Surface Profile of the Baseline Alignment

A profile must exist for the subassembly to attach to. 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. In this example, the intention is to use the existing ground surface along the horizontal alignment to define the top of the overlay at the baseline.

### 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 under Assembly in the Create Design panel of the Home tab. Insert the **OverlayMillAndLevel2** subassembly, assigning the parameters as shown in Figure 15. 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 keep the bottom of the overlay 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 15: OverlayMillAndLevel2 subassembly shown with recommended parameters for this example.

| Parameters                      |                       |
|---------------------------------|-----------------------|
| Left Overlay Slope              | -2.000%               |
| Right Overlay Slope             | -2.000%               |
| Version                         | R2013                 |
| Superelevation Axis of Rotation | Unsupported           |
| Crown Point Offset              | 0.0000'               |
| Left Sample Point Offset        | -12.0000'             |
| Right Sample Point Offset       | 12.0000'              |
| Left Trim Point Offset          | -12.0000'             |
| Right Trim Point Offset         | 12.0000'              |
| Left Overlay Slope Options      | Match slope           |
| Default Left Overlay Slope      | -2.000%               |
| Right Overlay Slope Options     | Match slope           |
| Default Right Overlay Slope     | -2.000%               |
| Slope Tolerance                 | 0.500%                |
| Use Profile                     | Use minimum clearance |
| Minimum Clearance               | 0.1250'               |
| Overlay Depth                   | 0.1250'               |

### 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

Use the Section Editor to check that the intent of the design has been met.

## Results

Using the Section Editor you should see that in most sections, 1.5" of leveling has been added to the existing pavement and topped with an additional 1.5" of asphalt overlay (Figure 16). In sections where there are ruts, additional material will be shown where the rut has been filled (Figure 17). 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 18). This has all happened automatically as a result of the parametric nature 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 may need to be added in order to achieve a constant slope between the existing ground at the baseline and existing ground at the EOP.

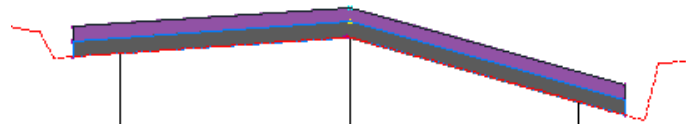


Figure 16: Typical section of road with 1.5" leveling and 1.5" overlay layers.

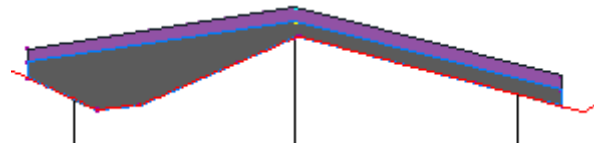


Figure 17: Additional leveling material (left side) required due to an existing rut.

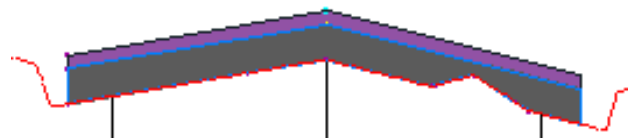


Figure 18: Leveling layer is deeper due to maintaining minimum 1.5" depth above raised area in existing pavement (right side).

## 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.

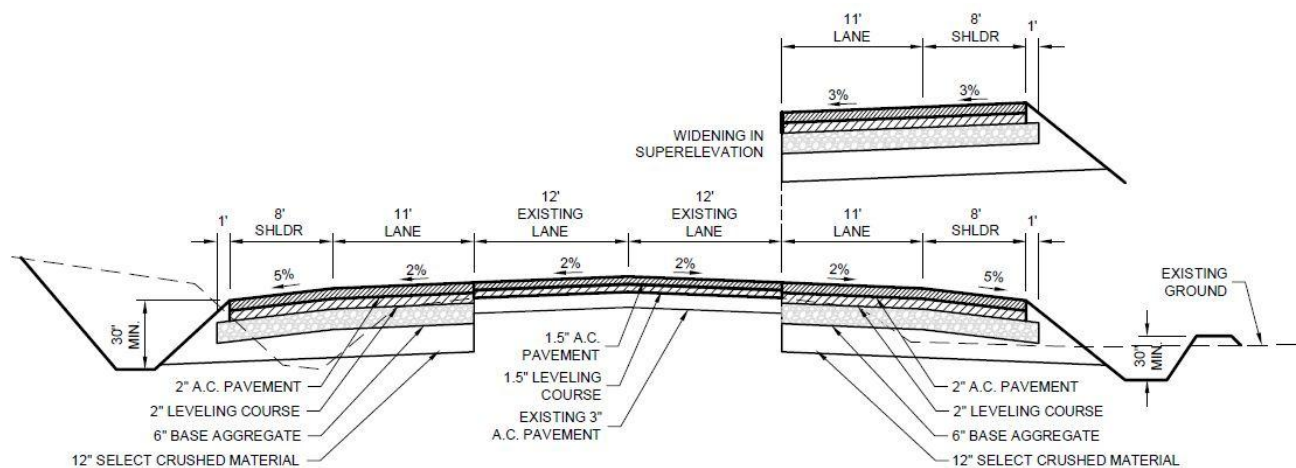


Figure 19: Typical Section

In Figure 19 we can see that the project typical section is asymmetrical with a lane and shoulder widening on both sides of the highway, with the added need to address a minimum ditch depth. With the cross slope of the paved shoulder at 5 percent, when in superelevation, the transition between the outside lane and the shoulder will need to be adjusted. The typical section also shows the need to daylight the sub-base material past the shoulder to the ditch slope.

To address these needs, a combination of the **OverlayWidenWithSuper1**, **LaneOutsideSuperWithWidening**, and **ShoulderExtendSubbase** subassemblies will be used. Also, in order to address the minimum ditch depth requirement as a result of existing storm drain conditions, the designer must be able to control ditch elevations independently, which will be handled via the **DaylightBasin** subassembly.

To help meet AASHTO superelevation requirements, an established AASHTO design criteria file will be used to compute superelevation rates and transition locations along the alignment of the existing road. These values will then be used to control the behavior of the **OverlayWidenWithSuper1** and **LaneOutsideSuperWithWidening** subassemblies at the time the corridor is built. In addition, widening will be applied to the **LaneOutsideSuperWithWidening** subassembly as needed to help meet 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 follow AASHTO standards should check [AutoCAD Civil 3D Services and Support](https://autodesk.com/support/autocad-civil-3d-services-and-support) at autodesk.com for information and a list of available Country Kits, which can be downloaded.

### The OverlayWidenWithSuper1 Subassembly

As explained earlier, the **OverlayWidenMatchSlope1** subassembly calculates the existing cross slope, and uses it to model the rehabilitation of the road. The **OverlayWidenWithSuper1** subassembly (Figure 20) behaves in a similar way. It will overlay the existing lane(s) and add new ones if desired. However, 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 *insert point* sets the outside edge.

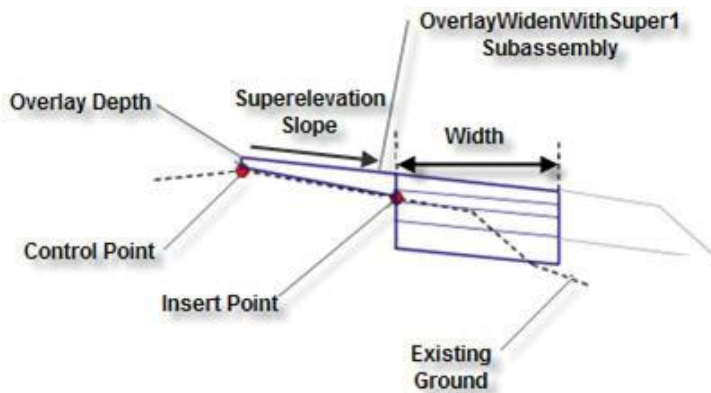


Figure 20: Schematic diagram showing the behavior of the **OverlayWidenWithSuper1** subassembly in this example: Non-zero overlay depth.

The *overlay depth* is applied at the control point. From the top of the overlay at this location, the slope defined by the superelevation rate at the location in question 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 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 widening component of this assembly.

### 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 (Figure 21) is intended for new construction but can be combined, as in this example, with a rehabilitation subassembly to help achieve the desired result. The key capability of this subassembly is that it automatically widens when needed, based on the radius of the horizontal design curve. This is accomplished through a formula that considers the number of lanes, radius of the curve, and the length of the wheelbase. To help ensure widening only happens in the curve area, the width value will be set to 0.01.

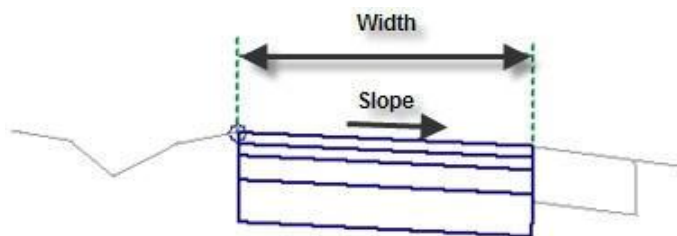


Figure 21: Schematic diagram showing the behavior of the **LaneOutsideSuperWithWidening** subassembly.

### The ShoulderExtendSubbase Subassembly

This subassembly is commonly used for new construction, but its use is also applicable to rehabilitation projects. The key functionality of this subassembly is that it obtains its slope value from the superelevation parameters of the baseline

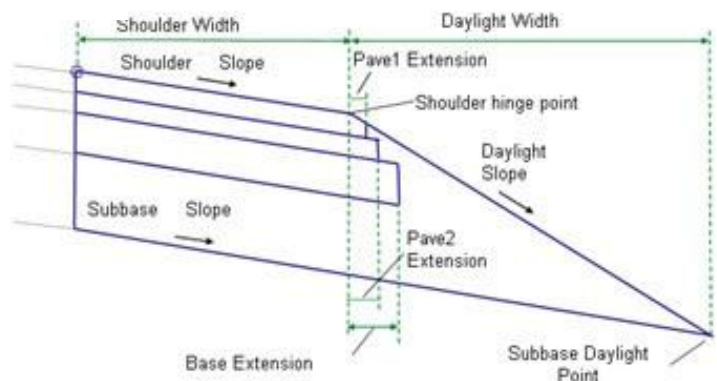


Figure 22: Schematic diagram showing the behavior of the **ShoulderExtendSubbase** subassembly.



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 to remove excessive breakover in superelevation.

### The DaylightBasin Subassembly

This subassembly will daylight 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 can control the elevations of the ditch using a feature line or profile.

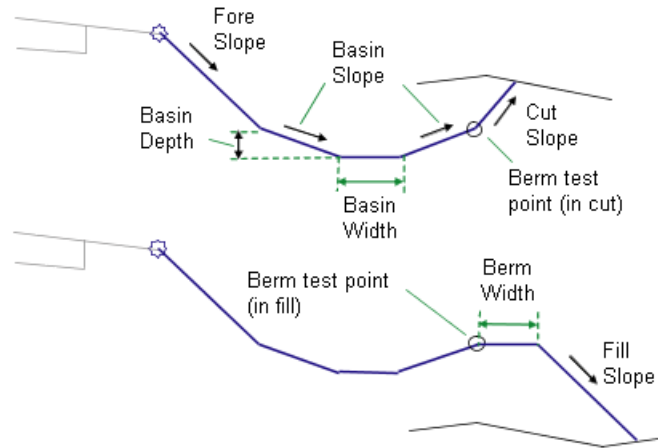


Figure 23: Schematic diagram showing the behavior of the DaylightBasin subassembly.

### 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. Create an existing ground Surface Profile of the baseline alignment.

#### 2. Create an Existing Ground Surface Profile of the Baseline Alignment

A profile must exist for the subassembly to attach to. This is typically generated as a result of a topographic route survey of existing conditions. In this example, the intention is to use the existing ground surface along the horizontal alignment to define the top of the overlay at the baseline.

#### 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 flow lines.

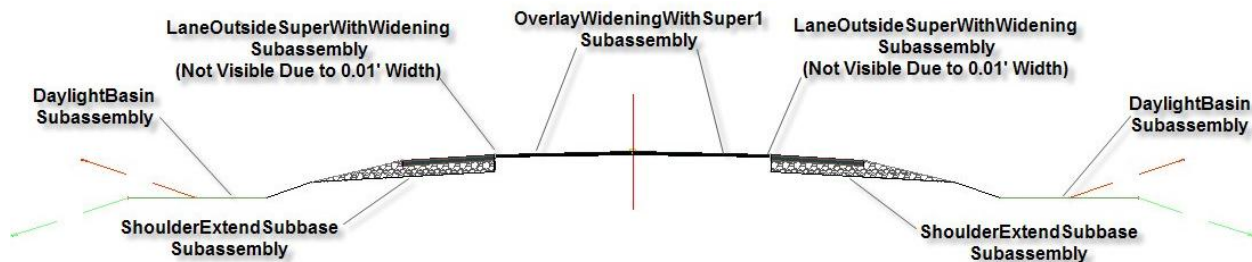


Figure 24: View of the completed assembly.

## 5. Build the Assembly

Begin building the assembly by using the Create Assembly command under Assembly in the Create Design panel of the Home tab. Add 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, essentially resulting in a depth of 0". Adjust other parameters based on 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 something like "Overlay-Right" and "Overlay-Left."

## 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 **OverlayWidenWithSuper1** subassembly. Assign the existing ground surface as the surface target for the **OverlayWidenWithSuper1** 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 25: 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. Review the Design

Use the Section Editor to check that the intent of the design has been met.

## Results

By examining the results using the Section Editor, you should find that sections that are not in superelevation consist of an overlay section between the existing edges of pavement, a new shoulder, and the newly designed ditch. The cross slope of the overlay section will be in normal crown, typically a -2 percent slope since the sections are not in superelevation.



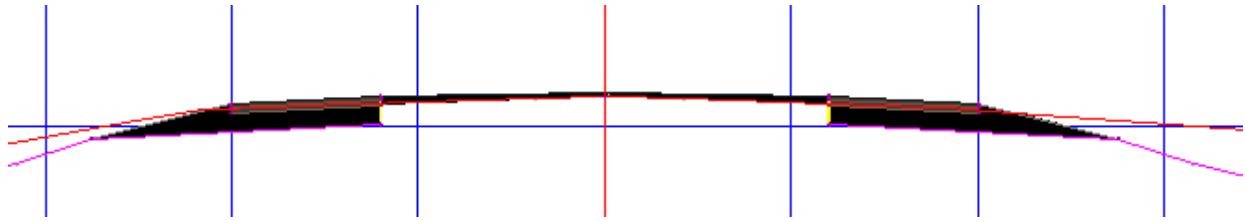


Figure 26: Normal crown section showing overlay and shoulders.

In superelevated sections, the overlay cross slope will be set to match the required superelevation based on AASHTO specifications. The **LaneOutsideSuperWithWidening** will extend outward due to its ability to widen based on the parameters set in the subassembly, and the outside shoulder will reverse its slope due to the breakover removal behavior assigned when defining the superelevation of the baseline alignment.

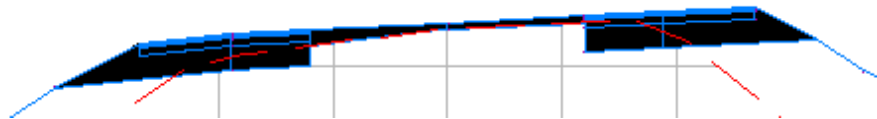


Figure 27: Section showing superelevated overlay and widening along with reversed shoulder slope on outer lane (right side) due to breakover removal.

You should also find that the ditch bottom elevations created via the **DaylightBasin** subassembly match the elevations defined by the basin elevation target that has been assigned.



Figure 28: Section view showing ditch created by DaylightBasin subassembly. The flow line 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 a roadway improvement project you are asked to provide a turning lane at a particularly busy intersection. The project also includes a 3" asphalt overlay that will be added to the roadway surface within the project limits. There will be a transition into the turning lane, so the width of the new lane will vary.

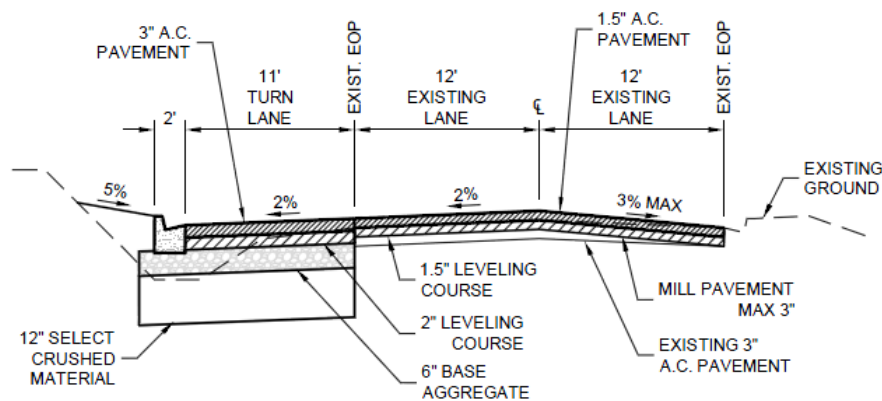


Figure 29: Typical Section

The Typical Section in Figure 29 shows the right side of the road will need to be milled and overlaid. This will be similar to

the first example where the **OverlayMillAndLevel2** subassembly was used for a crown condition. The **OverlayMillAndLevel1** will give us the same functionality, but is used for situations from the baseline outward. The left side of the typical section looks similar to the left side of the third example where **OverlayWidenWithSuper1** was used. The difference, as seen in the typical section, is that superelevation does not need to be considered and the overlay and widening will only be on the left side. In this example, we will attach a curb and gutter subassembly to the outside edge and a simple catch slope using the **BasicSideSlopeCutDitch** subassembly. The **OverlayWidenMatchSlope1** subassembly will provide the capabilities and parameters needed to create the new turn lane. In addition, the **OverlayWidenFromCurb** subassembly will be used to go around the new curb return.

### The OverlayWidenMatchSlope1 Subassembly

In our example, this subassembly will provide an overlay between the *Sample Point* and *Insert Point* by matching the cross slope of the existing pavement. To the outside of the overlay, it will provide full pavement structure to a desired width. A target can be used to define the width parameter in situations where the width needs to vary to accommodate the transition. The 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 lane, while on the opposite side of the road the **OverlayMillAndLevel1** subassembly will be used.

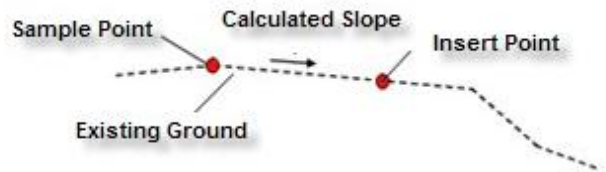


Figure 30A: The elevation of the target surface at the Sample Point and Insert Point is used to determine the existing cross slope.

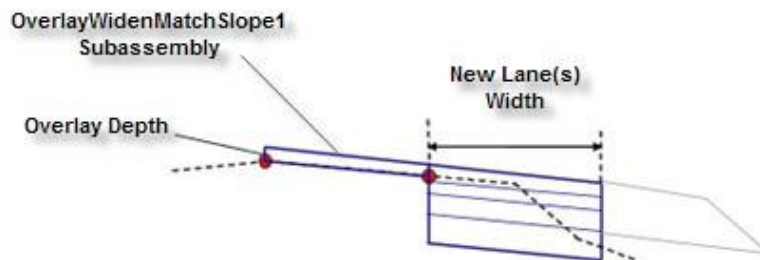


Figure 30B: Schematic diagram showing the behavior of the OverlayWidenMatchSlope1 subassembly.

### The OverlayWidenFromCurb Subassembly

This subassembly is similar to the **OverlayWidenMatchSlope1** subassembly in that it provides a full pavement structure widening and matches the existing pavement cross slope, except it targets inwards from an existing or proposed curb flange point to an offset target. The attachment point is at the outside edge of the widening section. The lane width value can be assigned a target in situations where the width varies. The overlay width and widening targets can be defined using an alignment, polyline, feature line, or survey figure, and the overlay elevation target can be defined using a profile, polyline, feature line, or survey figure (Figure 30C).

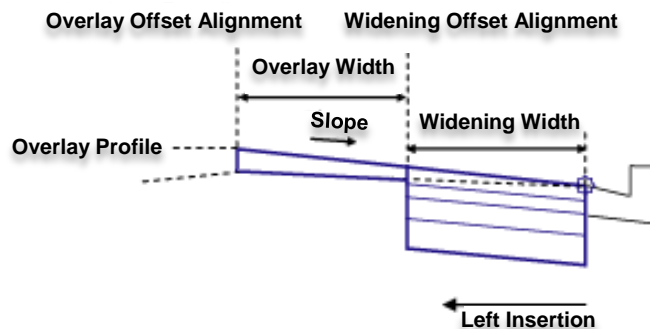


Figure 30C: Schematic diagram showing the behavior of the OverlayWidenFromCurb subassembly.

## 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. Create an Existing Ground Surface Profile of the Baseline Alignment

A profile must exist for the subassembly to attach to. 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. In this example, the intention is to use the existing ground surface along the horizontal alignment to define the top of the overlay at the baseline.

### 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 defined using an alignment, polyline, or feature line.

### 5. Build the Assembly

Begin building the assembly by using the Create Assembly command under Assembly in the Create Design panel of the Home tab. Insert the **OverlayWidenMatchSlope1** 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 right side of the road, since an overlay is the only requirement, a subassembly such as **OverlayMillAndLevel1** can be used.

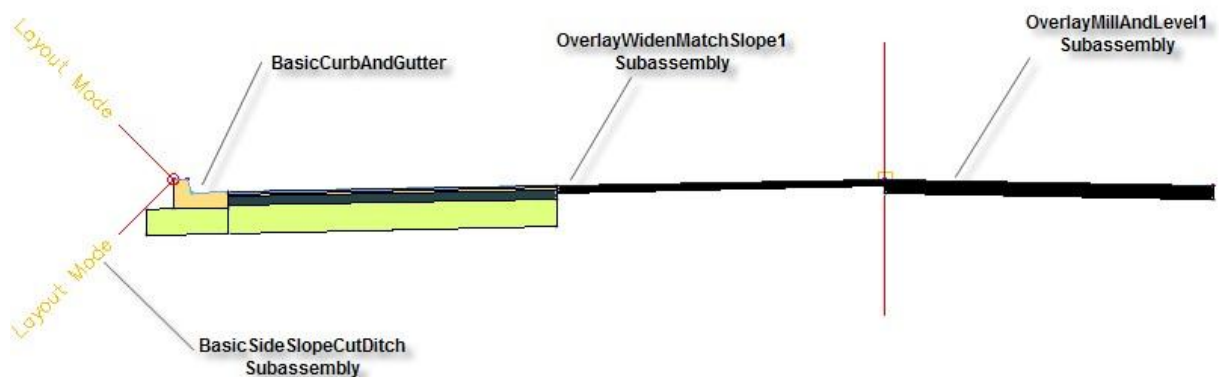


Figure 31: View of the completed assembly showing overlay and widening on the left side and overlay on the right side.

### 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 EOP targets to the Insert Point Offsets for the **OverlayWidenMatchSlope1** and the right EOP targets to the **OverlayMillAndLevel1** subassembly. 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 new EOP of the turning lane.

### 8. Review the Design

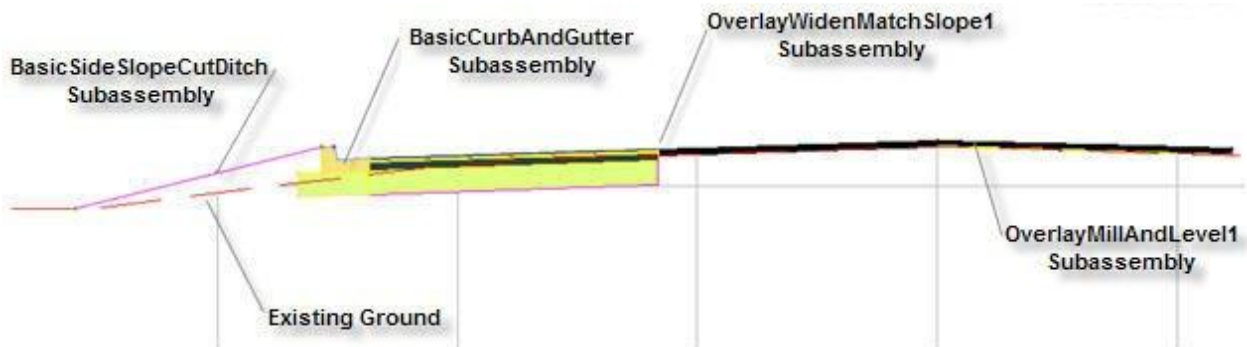
Examine the results using the Section Editor to check that the intent of the design has been met.

| 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 32: 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.

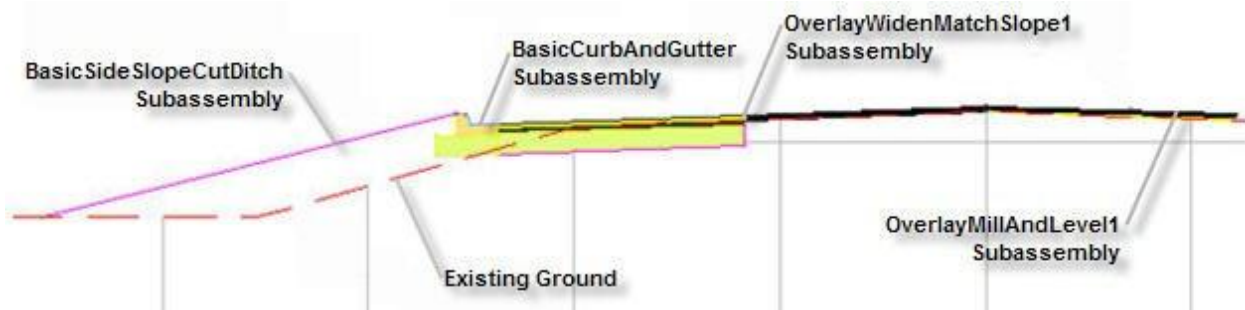
## Results

As you review 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 33: Section view showing overlay and widening (left side) and overlay (right side).**

In the transition area, as the road transitions from the full lane, the section will be similar but with a narrower widening region.



**Figure 34: Section view showing overlay and widening in transition area. Note the narrower widened area compared to Figure 33.**

## Example 5: Driveway Curb Cuts

AutoCAD Civil 3D software provides the ability to develop and use custom-built subassemblies that can match the varying design criteria and unique conditions of road and highway rehabilitation and reconstruction projects by developing them using Subassembly Composer.

In this example, we'll consider the need to provide an additional lane with new curb and gutter along a stretch of road that has a large number of existing driveways. This project also contains other improvements on a roadway section completely on tangent. In addition, a 3" overlay is being applied throughout the project limits.

In the previous example, you used the **OverlayWidenMatchSlope1** to target an offset in order to widen the road. We will use it for the same purpose here.

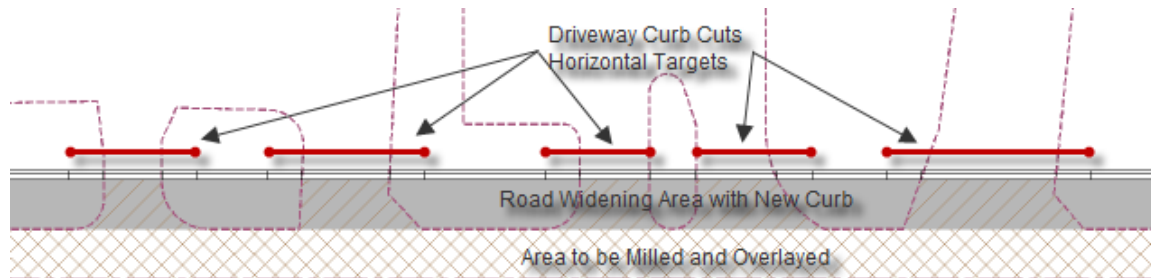


Figure 35: Partial Plan diagram.

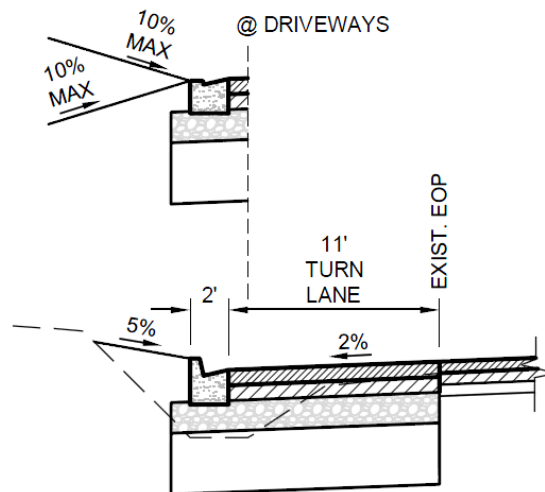


Figure 36: Typical Section

As shown in the Typical Section (Figure 36) the designer is required to maintain a driveway grade of not more than ten percent and will need a low profile curb type across each driveway location. Since no subassembly exists “out of the box” to do this, we will create a subassembly that changes its curb shape when in a driveway section. This custom subassembly also needs to use a typical cut and fill daylight slope and be able to create a driveway slope in cut and fill conditions. For the purposes of this paper we'll call this subassembly **ASCCurbDrivewaySurfaceLink1**.

### The **ASCCurbDrivewaySurfaceLink1** Subassembly

This subassembly will insert a full height curb and gutter shape or a driveway curb shape depending on whether an offset

target is detected. It will have a link to the surface component that has different user-defined slope parameters based on detection of the offset target and the cut and fill condition.

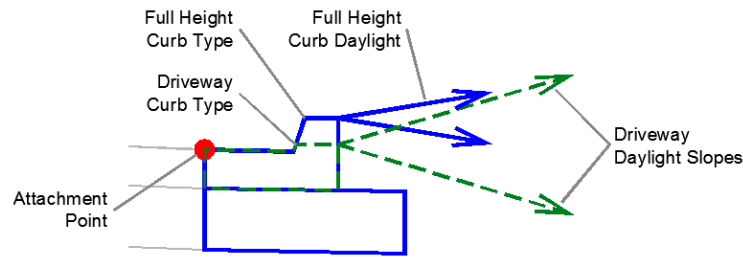


Figure 37: Schematic diagram showing the behavior of the ASCCurbDrivewaySurfaceLink1 subassembly.

## Design Steps

In this example we are adding a new baseline to an existing corridor that has an edge of travel way defined.

1. **Create the Custom Subassembly in Subassembly Composer**  
Define the custom subassembly parameters and import the subassembly into your subassembly Tool palette.
2. **Define the Baseline Alignment**  
The edge of existing travel way (ETW) alignment used to define the lane widening described earlier will serve as the baseline alignment. The geometry of this alignment can be reconstructed from highway design plans, or from a right-of-way survey.
3. **Define the ETW Profile**  
Create the surface profile from the corridor surface at the edge of travel way so the attachment point of the new curb assembly will match vertically.
4. **Define the Driveway Offset Targets**  
These targets can be provided as alignments, polylines, or feature lines.

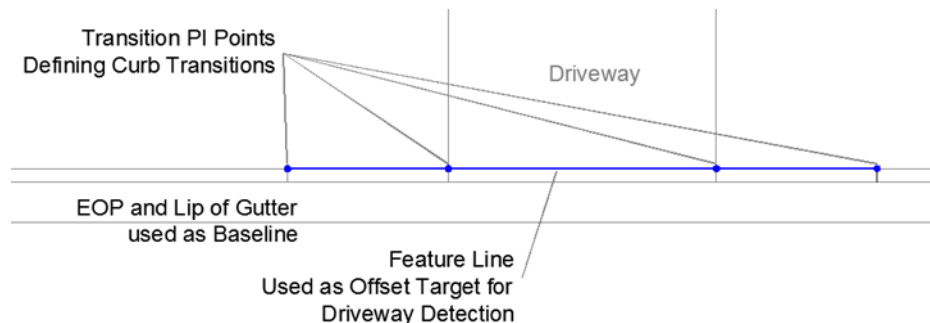


Figure 38: Schematic diagram showing Offset Target feature line.

5. **Build the Assembly**  
Begin building the assembly by using the Create Assembly command under Assembly in the Create Design section of the Home tab. Insert the ASCCurbDrivewaySurfaceLink1 subassembly on the left side.
6. **Build the Baseline**  
Add the baseline alignment using the ETW alignment, the corridor ground profile, and the assembly created in the previous step.
7. **Assign Targets and Frequencies**  
Assign the multiple driveway offset target objects to the ASCCurbDrivewaySurfaceLink1 *Curb Type* parameter, created when developing the subassembly in the Subassembly Composer.
8. **Review the Design**  
Examine the results using the Section Editor to check that the intent of the design has been met.



## Results

As you view the design, the full height curb and gutter and the daylight slope matching the cut and fill design criteria are added outside the widened road. As you iterate through each section, a driveway curb type and slope will be automatically added at each driveway.

### Finalizing the Design

Once the corridor is built (as described in the previous examples), there is usually some additional work required to address minor design issues and to extract information from the design. The most common issues are listed and described below.

## Using the Corridor Section Editor

The Section Editor, which you used to examine results in each of the examples, enables you to view the design from a cross-section perspective without actually creating cross-section views in the drawing. The Section Editor provides the option to select which Civil 3D objects to show in the section view, such as other alignments, profiles, pipe network components, feature lines, parcel geometry, and points defined in point groups. In the example of adding driveway cuts this may be useful to show feature lines representing the driveway edges in order to help see if the custom subassembly is defining the curb and daylight properly and fine-tune any changes that may be required in the sections.

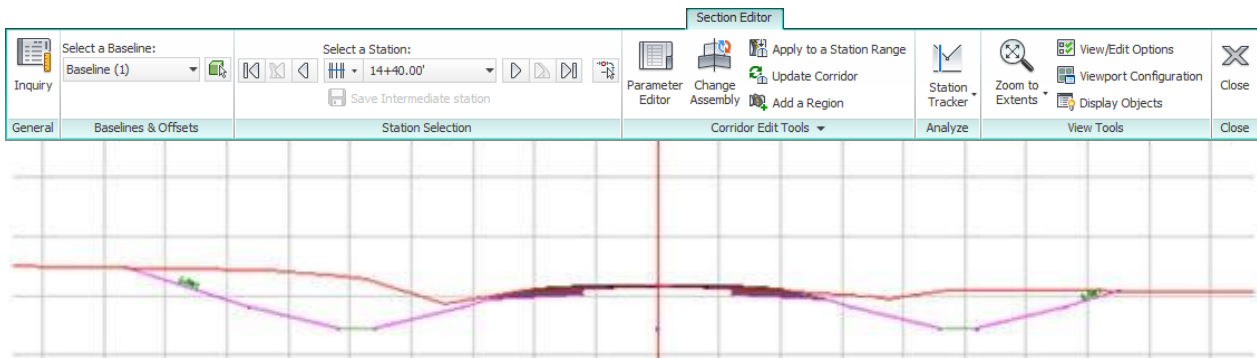


Figure 39: The Section Editor.

Often during a road rehabilitation project, conditions arise that the assembly being used does not adequately address. To accommodate this, the Corridor Section Editor can be used to apply assembly overrides to a corridor section, a range of sections or even a region that is added within the Section Editor. This will enable you to start the road corridor model with more typical section assemblies and then fine tune at a later time where required.

To assist in the review of sections, the Section Editor provides the ability to create multiple viewports, which enables you to view sections and follow station locations in both plan and profile view.

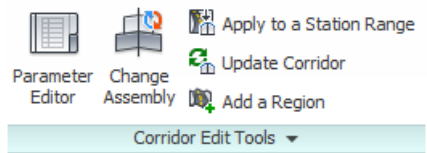


Figure 40: Corridor Edit Tools.

For further information on how you can use the Section Editor capabilities to assist with your design review, consult [AutoCAD Civil 3D Knowledge](#), or additional Autodesk documentation located in the [AutoCAD Civil 3D Support](#) section on autodesk.com.

## Additional Corridor Sections

When the corridor is built, the corridor section interval is specified. Often, key transition points occur between the corridor sections, causing irregularities in the geometry as shown in Figure 41.

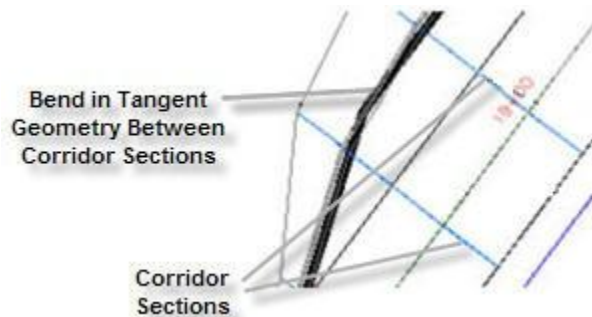


Figure 41: Plan view of corridor showing improper construction of the corridor due to a bend in an offset target occurring between corridor sections.

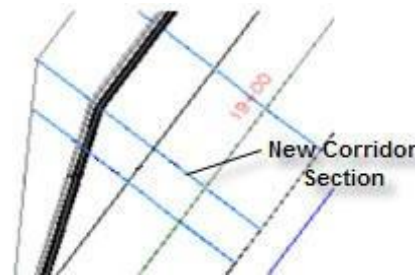


Figure 42: Add assembly frequencies using Frequency to Apply Assemblies, which can be accessed in the Corridor Properties dialog box.

To accommodate for these key transition points, additional sections can be created by changing the Frequency settings in the Corridors Properties dialog box. The Frequency settings tab also enables you to add individual stations by selecting precise points in the drawing, as well as automatically adding target geometry through the At Offset Target Geometry Points option. In Figure 42, you see an additional corridor section was added by selecting the bend in the target polyline. Note that the corridor geometry properly follows the target geometry after the change is made.

## 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 of the roadway model. This can result in an uneven or bumpy profile when you consider the corridor model longitudinally.

This type of situation can be addressed by using two or more design iterations. For example, let's look at Example 1, on page 7. 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 using the Create Profile from Corridor tool.
2. Display that profile in a Profile View and edit the profile to help provide smoothness and work towards compliance with safety standards by using Create Best Fit Profile in the Create Design section of the Home tab.
3. Edit the corridor model and reset the parameters of **OverlayMillAndLevel2** to use the modified profile, and rebuild the corridor.
4. Use the Section Editor to examine the results and 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.

## Using 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 the cross-section view. Material Area Fill styles can be applied to code set styles to add plan view hatching or shading. Through effective application of codes and code set styles, you can help make the design easier to analyze, more visually appealing, and standardized for sheet production. As seen in Figures 43 and 44, a lot of information can be conveyed by simply applying a well-built code set style. Once the code set is in place, this information displays automatically and does not require additional effort by the designer.

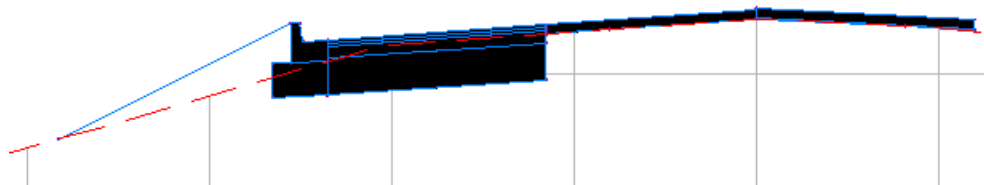


Figure 43: Section view using a Basic code set style.



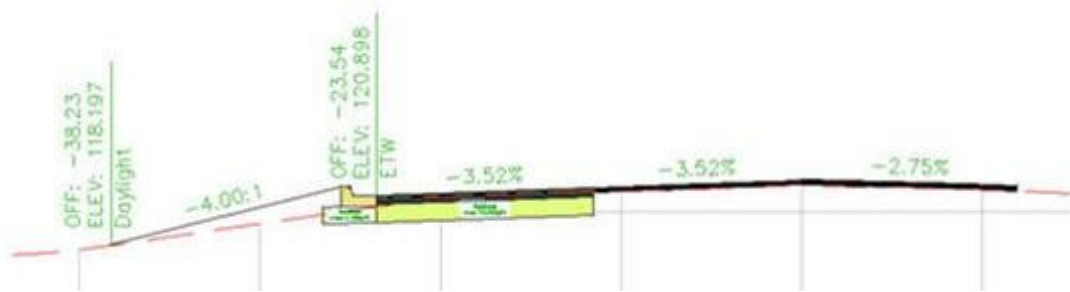


Figure 44: Same section view using a customized code set style. Note the labels, as well as the differentiation between materials.

## Creating Section Views

Often the final step in finalizing the design is creating cross-section views and, ultimately, cross-section sheets. 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 locations along which Civil 3D will cut sections through the corridor, surfaces, and even pipe networks so that the information can be shown in section views. To begin the process of creating sample lines, launch the Sample Lines command in the Profile & Section panel on the Home tab. Select the baseline alignment for the corridor and create the Sample line group. The Sample Line Tools toolbar will then appear, providing various commands for generating sample lines. Typically, sample lines are generated using 'By range of stations' as shown in Figure 45. This command will generate multiple sample lines along given intervals. When executing this command, you can control the interval along curves, tangents, and spirals separately. You can also specify the width of the left and right swath and the addition of sections at critical superelevation stations.

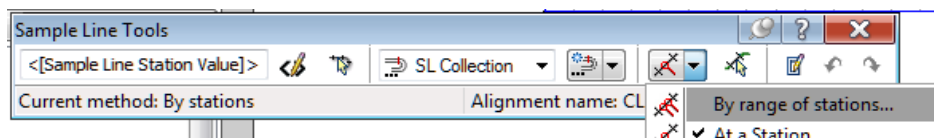


Figure 45: By range of stations command being utilized on the Sample Line Tools toolbar.

### 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 enable Civil 3D to automatically group the section views into sheet arrangements, making it easier to display and plot the section views within your company's standard title block. The group plot styles in Civil 3D are dynamic so layout changes and spacing configurations can be made in the group plot styles and be automatically updated within the sheet diagrams in the drawing.

### 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.

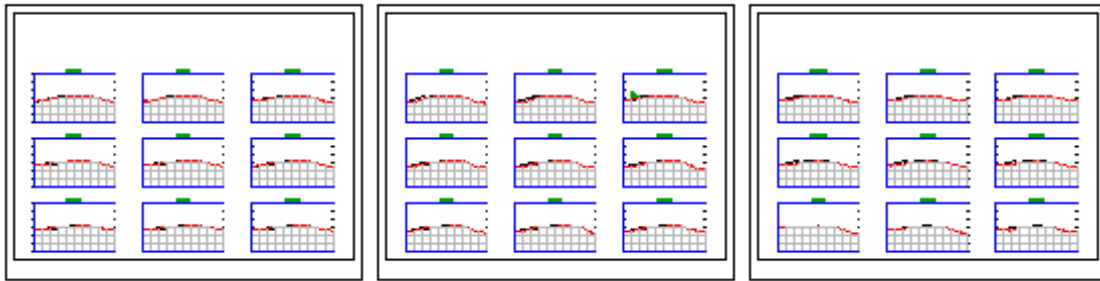


Figure 46: Section views plotted using a group plot style.

## Conclusion

The goal of this white paper is to illustrate how AutoCAD Civil 3D can be used for road reconstruction and rehabilitation design by explaining key concepts and providing real-world examples. Civil 3D uses corridor targets to help produce a more dynamic design. Utilizing targets, the corridor model interacts 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, parametric subassemblies, used in conjunction with surface targets, help you to analyze existing conditions and match conditions such as cross slope in an efficient fashion. Similarly, offset and elevation targets can be utilized to automate the creation of lane widening, control the elevations of ditches, and define the limits of an overlay, versus the manual editing of these values, section-by-section. AutoCAD Civil 3D also includes a variety of commands and procedures that aid in finalizing the design—enabling 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 project. The use of Civil 3D software helps simplify these types of designs by accessing the intelligence of the existing conditions as well as BIM for Infrastructure workflows, improving the quality of designs and aiding you in completing them in less time and with greater accuracy.