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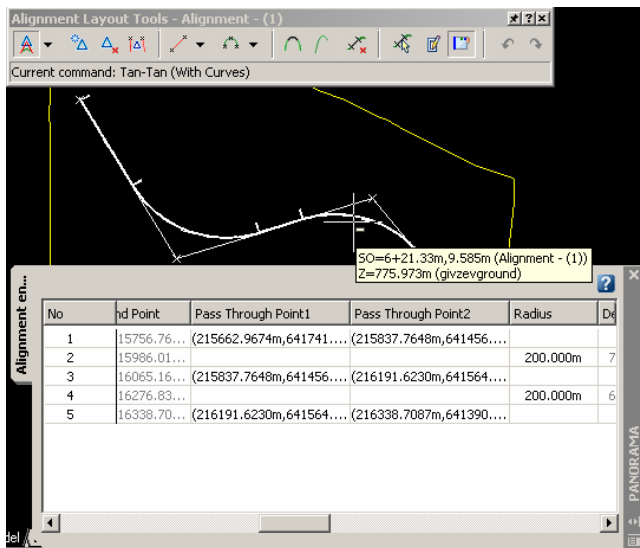
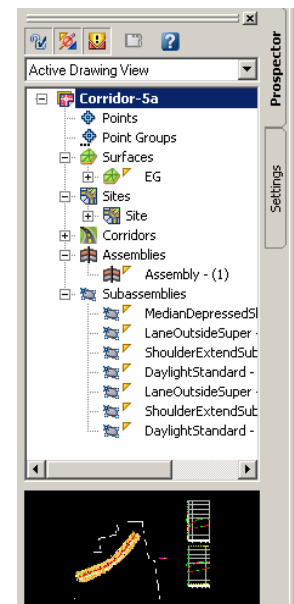
White Paper

Comparing Autodesk Civil 3D 2005 and Bentley MX Software

Executive Summary

Deciding which software to adopt can be a challenge, especially in the traditionally conservative civil engineering field. Civil engineers may be reluctant to adopt new technology; many, in fact, would be perfectly content to continue using slide rules for calculations and straight edges for drafting. The introduction of affordable computers and software into the design office has sometimes been seen as a threat to the engineer's role, forcing engineers to rethink how they can use new technology to apply their professional skills.

Many companies that have been using Bentley® MX software (previously, Infracore and MOSS) have defined their civil engineering software needs around MX as it has evolved over the past two decades. Although engineers may be reluctant to change, we should not turn a blind eye to the impressive advances that design software has taken over the past few years. Most other engineering disciplines are already using parametric 3D model-based design software as mainstream technology. Civil engineering is one of the last bastions of old design technologies.



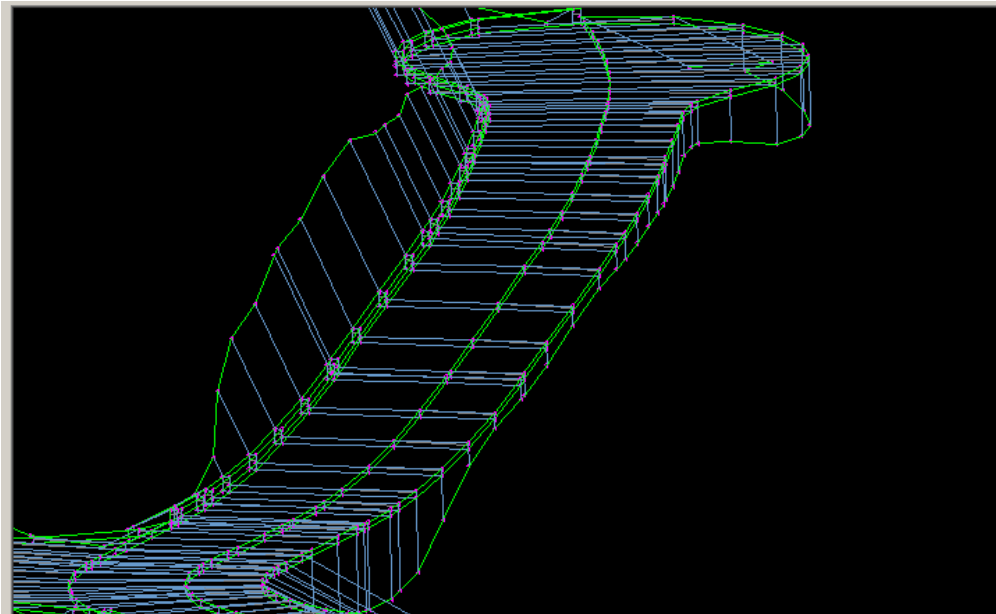
A Civil 3D object-based alignment

Comparing Autodesk Civil 3D 2005 and Bentley MX Software

Parametric model-based 3D design for civil engineering is available today with Autodesk® Civil 3D™ software. The object-based Civil 3D approach to design means that the software's intelligent objects recognize their form, fit, and function in the real world. For example, to a civil engineer, lines and curves represent an alignment that provides horizontal and vertical control for a roadway, railway, or other corridor design. When those lines and curves are intelligent objects, the software understands the relationships between them and reacts accordingly when, say, a curve's radius becomes too small or a line's length becomes too short. In object-based design, when an object is changed, all related objects update accordingly. The ability of objects to react to each other is what defines parametric modeling. The technology in Civil 3D software is unparalleled in any other mainstream civil engineering software today.

Model-based, 3D technology is clearly the forward-looking approach to civil engineering design. Because both Autodesk Civil 3D and Bentley MX software provide 3D modeling capabilities, this paper focuses on the differences between these software applications to provide a broader picture of the technological and business advantages of Civil 3D over MX.

The main differentiator between Autodesk Civil 3D and Bentley MX software is the approach to generating the road design model. MX employs a string modeling approach which defines longitudinal feature lines based on offset parameters from the design centerline, and Civil 3D creates a model based on generated cross sections that are linked together. Both applications provide a 3D model of the design project, but from a different perspective. This paper details the pros and cons of each approach.



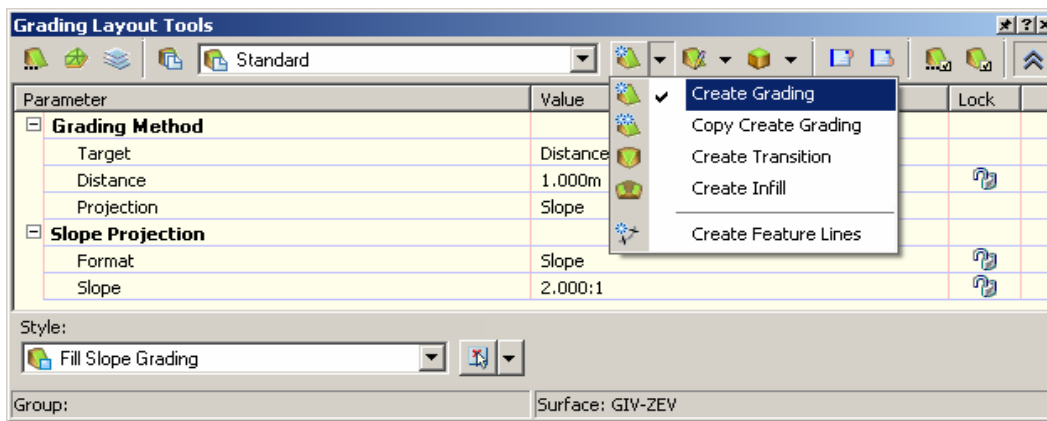
Bentley MX uses the string modeling approach to create the 3D model. String modeling advocates contend that this method is the most accurate way to generate a model, especially when dealing with the complex interactions associated with at-grade and multilevel interchange design. Although MX may provide a good model of the project, it is not flexible in terms of design changes. Changes to any key elements of the design centerline require the designer to manually rerun all the other design commands used to create the resulting feature strings from the master centerline. In addition, although the MX string modeling approach is well suited for the top design surface, generating related geometry data such as the road pavement layers, subbase, and subgrade is not automated.

MX provides tools to generate this data, but they must be run manually after changes have been made to the top surface design.

In contrast, using Autodesk Civil 3D software, engineers can change the design at any time, and all dependent objects are automatically regenerated. The benefits of such automation are clear: designers can save significant time in the redesign process, typically part of any design project. Especially in the preliminary phases of route selection and cost estimation, Civil 3D provides a corridor model that can generate all the necessary information for project drawings as well as quantity takeoffs. Evaluation of different alignment options takes just seconds, from design change to the updated model and resulting drawings and quantities.

Another advantage of Autodesk Civil 3D is the ability to incorporate associated alignments into the design model. In MX, designing drainage ditches associated with roads is tedious, especially when the grade of the ditch must be adjusted independently of the road profile, which is true in all but the simplest cases. Changes to the road profile may necessitate not only a change in the hydraulic grade line but in the plan position of the ditch itself based on typical slopes and elevations from the main roadway. In Autodesk Civil 3D, however, the corridor model can easily be adapted to include secondary alignment control for ditches, which can be generated and updated effortlessly when the road design changes.

General Site Design: Autodesk Civil 3D Versus MXSite



The Grading Toolbar

Site design differs from road or rail design in that it is not typically based on an alignment with planimetric and vertical controls. The plan layout of such a design is generally governed by site parameters for building lots, parking areas, and so forth. The main challenge in such design is to find an optimal engineering solution for proper surface drainage, cut and fill slopes, and balancing of earthworks. In addition, the design needs to be properly drafted, and quantities must be generated for bidding and construction.

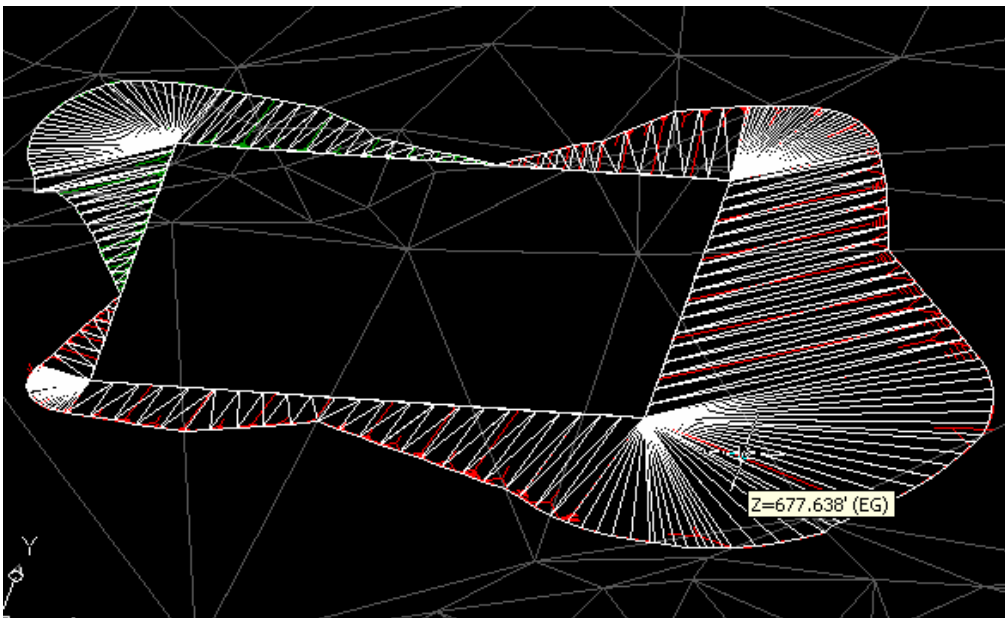
For a site designer, Autodesk Civil 3D software has many distinct advantages over Bentley MX software. MX does have an MXSite™ module; however, as with most MX products, it was designed for a particular type of user, namely, U.K. housing development companies. Although the MXSite package does have some built-in productivity tools, it is rigid and dependent on a specific design workflow. Trying to adapt the MXSite product for a different design process can be difficult. In addition, string modeling is not ideally suited for site design. String modeling defines related strings from a baseline string—ideal for roadway

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and other linear projects but less suitable for general site design. While using the MX tools for site grading, one gets the impression that Bentley has retrofitted a less-than-ideal concept to solve site grading problems.

Autodesk has invested much more in core technology for site development, specifically in the grading features of Autodesk Civil 3D. The grading functionality has evolved into a set of object-oriented tools that enable the designer to interact with grades and slopes from 3D features. Intelligent grading objects in Civil 3D software react appropriately to other grading objects in a site, automatically solving the complex 3D interactions involved in convex and concave corner overlapping of design slopes. In addition, users can define the grading parameters as a style and quickly iterate the design to find optimum levels for balancing earthwork volumes. Any changes in the layout are automatically updated in the model and resulting drafting, labels, points, and volumes. Although many of these tasks can be done in MXSite, they require their own set of commands and user interaction to attain the final output.

Most site design starts with a 2D layout. Lot lines, property ownership, and other zoning considerations are a major factor in the initial stages of site design. Autodesk Civil 3D provides powerful routines to automate parcel layout and design. Laying out standard-sized lots along a proposed right of way can be frustrating without the tools provided by Civil 3D. MXSite has few tools to efficiently work with the design of 2D parcels.



A grading object tied into an existing ground surface

Autodesk Civil 3D software changes the way engineers do site development and analysis. Many manual tasks that previously took days to complete can now be done in seconds with Autodesk Civil 3D.

Lastly, one must remember that we design in order to build. Through the use of styles for contours, labels, and points, the design can easily be transmitted to accurate drawing information for construction purposes. The point objects in Autodesk Civil 3D can be uploaded directly to surveying and construction equipment. Through the use of LandXML, which Civil 3D supports, high-quality design data flows easily from surveyor to designer,

through the approval process, and out to the field for construction without compromising data integrity. Because Civil 3D is based on AutoCAD® software, it includes all the power of AutoCAD for dealing with data import and export from outside consultants and partners as well as other design systems that support the AutoCAD DWG file standard. In MX, it is a manual process to meet the drafting and data communication requirements resulting from design changes.

Designing Urban and Minor Roadways: Autodesk Civil 3D Versus MXRoad

In contrast to design of major highways where a typical cross section can run along a length of road and remain relatively unchanged, urban and minor road design is characterized by a high degree of change from one section to the next. In addition, the alignments providing the horizontal and vertical control are frequently adjusted to ensure that the final design works in an environment with limited rights of way. As-built alignments themselves are often nontangential, differing from the theoretical design parameters to adapt to real-world constraints. Other infrastructure such as storm and wastewater drainage, electric, telecom, gas, and other utilities typically also need to be incorporated into the design.

MXRoad™ software users are probably familiar with the phrase *string naming convention*—a naming system developed so that additional information such as a string's associativity to master alignment strings could be easily determined. One of the drawbacks of this approach is that the designer is limited to 36 alignments in the MXRoad model. Although this number seems large, it can be a limiting factor in subdivision design and urban planning. In addition, there is no way to assign names to alignments in MX. Alignments are identified by a letter or single-digit number. The only place to identify roads by their actual names or numbers is in final drafting. Throughout the design process, the engineer must use codes to reference roads, which may lead to mistakes and wasted time.

In minor road and urban road design, the ability to set out alignments is central. Autodesk Civil 3D incorporates a full suite of alignment creation features to define parameters and constraints as part of an alignment object. MX users accustomed to full alignment find the same types of elements available in Civil 3D—floating, free, and fixed elements that can be combined to generate an alignment. In contrast to MX, however, these elements are part of an intelligent alignment object that reacts appropriately to the objects around it, facilitating the design process. Once the initial elements have been defined, the engineer can tweak parameters graphically or through a tabular editor to attain the optimal alignment. This capability is crucial in an urban setting that requires constant balancing of design parameters with right-of-way constraints resulting from existing infrastructure.

Autodesk Civil 3D vertical alignment tools are similar to the horizontal alignment layout tools. In addition, Civil 3D designers can use vertical curve types other than parabolic when they need to define circular vertical curves. Civil 3D also has the ability to superimpose other alignments on one alignment view, making it easy to coordinate associated vertical alignments such as in roundabout design.

The Autodesk Civil 3D corridor model offers many advantages over MX when it comes to minor roadways and urban road design. The corridor model is the central object for roadway design. It is based on and reacts with horizontal and vertical alignments, and assemblies (typical cross sections) that are based on subassemblies and gradings. The corridor model can also generate features (strings, in MX terminology) and surfaces. Styles can be applied to the resulting surfaces to generate finish grade contours and dynamic labeling.

In contrast to MX, each subassembly in Autodesk Civil 3D can represent any feature that is part of the roadway both for quantity calculation as well as final drafting. Assemblies can include pavement layers and other details that need to be incorporated into final drafting.

MX separates the concept of pavement design from the modeling of roadway geometry. When producing final drafts of cross sections, MX users must define strings for every feature needed in the cross sections. These strings then need to be associated to drawing routines and symbols to accomplish final section drafting. Even when this process finally works, it cannot be considered a fully integrated design and drafting solution.

Another advantage to the corridor model is that it may be resampled at any point in the design. Typically, the design engineer decides to take sections of the design every X meters along tangents, curves, spirals, and any other relevant point where the geometry changes. In MX these sampling points must be determined at the time of alignment creation. Typically, as the design becomes more complex, the engineer needs to generate sections at a higher sampling interval or at other crucial points in the design, especially in an urban environment. In Autodesk Civil 3D, the designer can change the sectioning interval or add crucial chainages at any time. Any changes in the base information defining the corridor automatically update the entire corridor model and all objects generated from the corridor. This capability transforms the design process.

Designing Major Highways: Autodesk Civil 3D Versus MXRoad

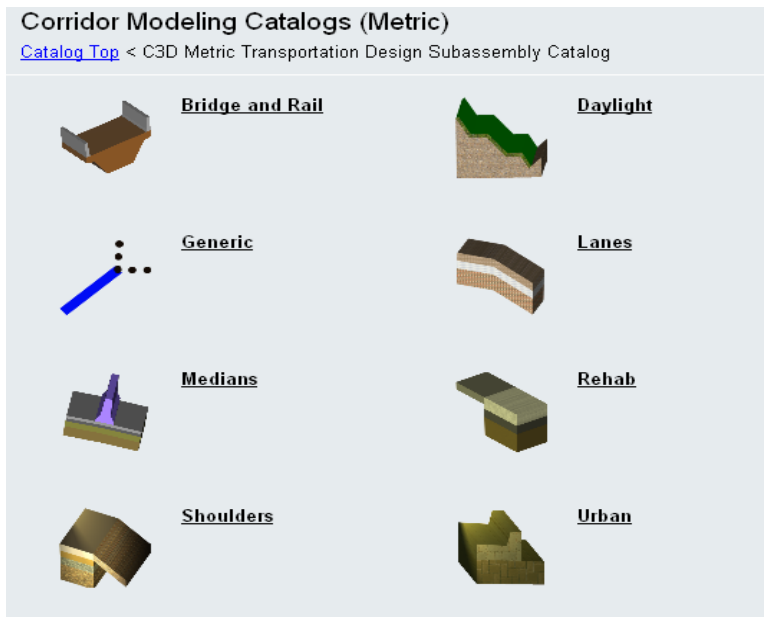
Major highway design has its own unique set of challenges. Although cross sections can be reused on long stretches of unchanging road, the designer must determine many other parameters to reach the optimal solution. Major highways typically have multilevel interchanges and bridges, complicated median areas, differing and split-level vertical control for opposing roadways, and more. The alignment itself typically incorporates spiral transition curves whose solution can be quite complex, especially for circular ramps and loops found in complex interchanges.

Autodesk Civil 3D provides advanced options for horizontal alignments in the initial layout of highways and interchanges. Alignments can incorporate loops and spiral transitions as are often needed in interchange ramps and along major highway alignments. Although MX has similar features, the resulting model is static. An MX user can obtain the same results, but the process is much slower and the resulting alignment is not dynamic. Any changes to the alignment return the designer to square one.

A powerful aspect of the Autodesk Civil 3D corridor model is its ability to bring together different alignments and assemblies into a single, unified design model. Although each roadway is typically designed independently in the definition phase, the interactions between them are often complex. Highway ramps, slip roads, medians, ditches, and closing slopes are all examples of seemingly independent design processes that need to come together for an acceptable corridor. These individual features can be adequately defined using MX string modeling, but there is no overriding feature to coordinate their interaction. At best, the MX user can cut sections of these independent design elements and draft them together.

For MX users, the limitations for urban and minor road design regarding final drafting of cross sections also apply in highway design. In contrast, Autodesk Civil 3D users can define their subassemblies and assemblies for situations where guard rails or concrete barriers are called for based on design parameters. Bridge sections can be fully defined, including the cross sectional characteristics of the particular bridge structure. The subassembly can be defined to automatically add a guard rail when the height of fill is above a certain criteria or slope. Retaining walls, ditches, and other elements called for in design can be defined parametrically, and the corridor can solve and place these elements appropriately. Again, MX has no equivalent design automation. The resulting Civil 3D cross sections are true drafted representations of the situation they describe, not just string cuts connected by lines or annotated by symbols in final drafting.

MX has a good set of tools for defining complex alignments and their horizontal and vertical interactions. However, this represents just one phase of the design process. The actual roadways must be defined by feature strings that are related to the master alignment strings defined by the MX designer. While the user may employ a naming convention, there is no relationship between the features defined and the master strings used for the initial layout. The consequence is clear: any changes to the defining alignments require the designer to rerun all the subsequent steps in the process. So although MX has a set of robust tools for the initial alignment definition phase, it lacks the tools needed to redefine the design. MX is ideally suited for the top-level surface design of a project. MX includes tools to define pavement layers, materials, and other subgrade surfaces, but they do not provide a unified approach to road design. Related subgrade and pavement features do not automatically react to changes in the design parameters but also need to be reprocessed to ensure coordination.



The subassemblies catalog in Autodesk Civil 3D

Conclusion

Bentley currently offers three MX civil engineering software solutions: MXRoad[®], MXSite[®], and MXUrban[™]. One must ask, however, what the future holds for MX customers in light of the fact that Bentley also has GEOPAK[®] and InRoads[®] software in their civil engineering product portfolio. Bentley has intimated that future versions of Bentley's civil engineering products will merge seamlessly using the best technologies from each system. Because of basic differences in string modeling and template-based techniques, it is not clear how Bentley will merge the products into a single, unified design package.

Many MX users may be disappointed by the fact that plans to develop a parametric system for MX products appear to have been abandoned. MX users should question Bentley as to

when they are likely to see a true object-based solution based on the string modeling foundation.

One of the key aspects of successful civil engineering software worldwide is the ability to tailor the look and content for local standards. Although most fundamental concepts of road design are the same worldwide, the engineering drawings vary widely from region to region. Because infrastructure projects are usually intended for local implementation, design drawings must typically meet strict guidelines and accepted practices for submittal.

Autodesk has done a good job in localizing Autodesk Civil 3D software by separating conceptually the design objects from the drawing implementation through object styles. Objects can be assigned a drawing style that can be manipulated down to the most minute detail. The user can assign these settings without knowing programming languages or coding. Designers can thus present information tailored to their client's standards, whether these standards are companywide, project specific, national, or international. The same is true of the project's design standards. Civil 3D incorporates localized design standards that can be further adapted to specific project requirements.

The productivity gains of combining a powerful, object-based design package with the world's leading drafting package cannot be overemphasized. In fact, many MX users do their final drafting in AutoCAD software. The ability to draft interactively while designing in Autodesk Civil 3D is unprecedented in the civil engineering design world. Through the style settings, designers are assured that their drawings are always synchronized and up to date. The potential savings for a typical design office on this issue alone makes Civil 3D a serious candidate for consideration.

Although Autodesk Civil 3D is still in its early stages of development, early adopters will find sufficient technology advances to merit an in-depth investigation of the product. Although some key features are somewhat lacking in comparison to MX, there are enough improvements in the technology to offset the temporary shortcomings in this new product.

When choosing design software, civil engineering firms must consider many factors, including purchase price, training costs, technology, potential productivity gains, data sharing, collaboration, future vision, stability of the technology provider, and more. Decisions made today chart the course for the next decade. Autodesk Civil 3D software is the clear path to the future.

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