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It's time for learning.

Models for Road Design

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Why should I change?

- "But the status quo is not a stream, let alone a 'mainstream'. It is a stagnant swamp. It is the innovators who carry mankind forward."
  - Ayn Rand
- They say that time changes things, but you actually have to change them yourself.
  - Andy Warhol
- If you don't like change, you're going to like irrelevance even less.
  - General Eric Shinseki, Chief of Staff, U. S. Army

Why should I change?

- The National Institute of Standards and Technology (NIST) released a report in 2004 quantifying the cost of inadequate interoperability among computer-aided design (CAD), engineering, and software systems in the United States capital facilities industry to be US$15.8 billion per year. The waste of $16 billion that could otherwise be used for more and better infrastructure is an astonishing and serious matter.
- According to the NIST report, the lion's share of the cost is from transferring information by paper processes. About one third of the cost is from re-entering printed information so it can pass from one software system to another. The other two thirds is the waste of time searching for information recorded on paper.
- Engineering design technology has begun an important transition: from automating traditional 2D drafting processes to developing 3D models as the basis of design.
- *The new approach may present an unwelcome learning curve for some users*, but the possibilities for more integrated, efficient design might be well worth the effort.

Why should I change?

- "We have a major infrastructure problem in this country," said Maureen L. McÂvey, an executive vice president with the Urban Land Institute, which recently published a report on global infrastructure issues. "The civil engineers have estimated that we have a $1.7 trillion shortfall in this country alone"
  - NY Times August 2, 2007
- "This administration failed to support robust investment in surface transportation and the funding to accompany it," Rep. Jim Oberstar, D-Minn., the Transportation Committee's new chairman this year, said at a news conference after the bridge collapse in his home state.
  When the next highway bill comes up in 2009, Congress won't settle for a "bargain basement" measure, Oberstar said.
  - MSNBC

Why should I change?

- AASHTO Construction Management Integration Technical Group (formed in 2006)
  - …a majority of project construction issues, including change orders, contract claims, and resulting cost and/or time overruns, are a result of issues that could have been addressed during preconstruction activities; and
  - …many aspects of construction management should be considered and included in project plans, specifications, and/or processes with the goal of "setting projects up for success"
- 2007 IHEEP Meeting next month
  - 13 presentations on modeling & electronic deliverables

Plan + Profile + XS

- Current design output is a set of drawings that graphically depict the location of the road, the vertical profile, typical and atypical sections, cross sections and details.
  - Cross sections show how the road design interacts with existing conditions and are a key part of the design definition.
  - To keep this paper-based output at realistic levels, designers prepare plotted cross sections at 50-foot intervals.
  - Cross sections are annotated with crucial information needed to construct the roadway
- Road design is a largely manual design process made up of separate steps using automated tools.
  - When you have completed all the steps, you have the data to produce a set of construction documents.
- Published construction documents never reflect how the design data is compiled.
- In a paper-based workflow, *many designers believe that what is plotted is what gets built*, regardless of how the plotted documents were produced (so why change?).
- Contractors have to convert this graphical information into hard location data to be staked in the field for construction. Or worse, convert paper plans and 2D electronic data into 3D models.

Plan + Profile + XS

- Engineering design for highway construction has traditionally resulted in a set of plans, specifications, and estimates. Plans are a graphical representation of the existing and designed surfaces and features. They consist of a series of two-dimensional views of the three-dimensional world (i.e., plan, profile, and cross-section views). This manner of decomposing and visualizing three-dimensional reality is a holdover from the slide-rule-and-pen-and-ink era and is deeply embedded in engineering and construction practice.
- The move towards three-dimensional modeling involves more than changing enterprise CAD software. It requires a new way of thinking about how the world is represented and how work is done.

Plan + Profile + XS

- There is consensus across the experienced community that the greatest bottleneck in workflow for GPS machine guidance is development of the necessary three-dimensional models from two-dimensional plans, profiles, and cross-sections.
- Ultimately, the new direction is towards a much more seamless three-dimensional survey / design / construct / inspect workflow. This requires a new set of business processes and, truly, a new way of thinking about how the virtual world and its infrastructure are represented.
- Designers will be required to create and maintain three-dimensional models. The models will become primary and the plans will become secondary. Digital signatures and digital rights will be used to maintain control of data.
- A comprehensive, managed, work and information technology environment is needed to make this happen (Fenton, 2006).

What's driving change?

- GPS Machine Control technology enable contractors to robotically control grading operations from digital models that define entities such as roadways, parking lots, graded areas, or building sites.

- Grading control works directly from the model, and the equipment operator does not interact with the grading controls.
- Robotic graders do not perform the typical smoothing from one section to the next that occurs with manually controlled grading.

What's driving change?

- Robotic control (GPS, laser, etc) of grading requires a surface model that accurately defines the surface to be constructed.
- Models consist of data files that the contractor loads into the control equipment to directly control the physical grading operations.
- Using this technology, a contractor can
  - begin construction earlier
  - control the grading operations more efficiently
  - eliminate stakeout errors
  - deliver a finished site to the client more economically

What is a "Model"?

Design Model

- To move to true model-based design, designers must change their way of thinking and the processes used during design.
  - Plotted construction documents will always be necessary, but these should reflect the model, not define it.
- The model supplied to the contractor is what the contractor will build.
  - Designers must be able to produce this model accurately and economically, and to respond quickly to design decisions that affect the final product.

Design Model Benefits

- Creating the design model becomes the core design process eliminating time-consuming, error-prone design sequences.
- The design model provides a single source of definition for the output model.
  - Everything that defines the output model resides in the data set.
- Since the design model creates the output model, designers can avoid laborious, sheet-by sheet checking of plotted information.
  - If the data model is correct, the output model will be correct as well.

Design Model Benefits

- Creating a comprehensive design model and viewing the output model clearly shows any errors in design.
  - Looking at tight contours, rendered surfaces, etc. quickly shows any problems.
- Since each part of the output model is based on the design model, this approach provides no opportunity for human error, such as transposing numbers, slipping decimal points, or pressing the wrong buttons on the calculator.
- Design changes are made quickly and accurately through the design and output models.
  - The more such dynamic links the software provides between parts of the data set, the easier this process becomes.
- Plotting revised drawings based on a revised design/output model requires little or no manual input if designers adhere to a strict design model approach

Output Model Benefits

- Using the model-based approach, an output model becomes immediately available for use. The contractor can feed changes to the model into the robotics minutes after being emailed to the job site.
- The digital format of the output model is more efficient to transport and use. Designers and contractors can email files, place them on memory sticks, and plug them directly into the control equipment.
- Since output models are based on mathematical data models, you can generate detailed data in the output model that would be impractical by any other method.
- An accurate output model is all the contractor needs. The output model should define every nuance of the design and should not require any subsequent calculations on the part of the contractor to implement the design on the ground.

Construction Benefits

- ***Increases Productivity and Efficiency***
  - Increases productivity by up to 50%
  - Reduces guesswork and costly rework by moving dirt right the first time
  - Reduces survey costs up to 90%
  - Increases material utilization
  - Reduces operating costs
  - Extends the work day
- ***Assists with Labor Shortage***
  - Reduces labor requirements and costs
  - Customers can get the job done quicker
  - Reduces need for staking, string lines and grade checkers
  - Empowers operator to check grade from the cab
  - Reduces labor for staking as job progresses
- ***Improves Employee Satisfaction and Retention***
  - In-cab display brings the design to the cab
  - Provides more responsibility and job satisfaction
  - Real time feedback on progress increases job satisfaction, eliminates guesswork and reduces operator stress
  - Improves operator skills and takes performance to the next level
  - Investing in the operator provides value and trust by investing in latest technology

Construction Benefits

- The definition of the project should go directly from the design model to the finished site without the need for plotted drawings, stakeout calculations, and other steps associated with manual grading.
- Eliminating these intervening steps saves time and reduces human error.
- *Designers must be able to create these models efficiently and provide the contractor an accurate model of the site.*

Transition to Model-based Design

- A true output model is a digital file that contains basic geometric entities with complex interactions that defines the finished product of the entire design process.

Modeling Workflow

- Create design planimetrics in a 2D or 3D DGN
- Obtain survey/original ground information
- Start Site Modeler New Project Wizard
- Create an empty Model
- Import base design into the Model
- Create a new Site Object and define elevations of the Site Elements while adding them to the Active Object.
- Continue creating Objects & Elements as needed
- Evaluate and analyze the Site Model, adjusting the Elements, Objects and the Model as needed.

Some Key Definitions…

- **Site Elements**
  - MicroStation graphics (2D or 3D) placed in a DGN
  - Assigned an elevation with SITE tools
  - Assigned a DTM Feature (breakline, boundary, contour, etc) with SITE tools
  - Can be moved, copied, modified, etc at any time in the design process
  - **Reference Element Association** saves the relationship between the Defined Element and the Reference Element. Changes to one will automatically update the other.

Some Key Definitions…

- **Site Objects**
  - Collections of Site Elements (unlimited #) that are grouped together to:
    - Define side slope – cut/fill slopes to ground, object or model
    - Establish merge order for Model creation (FIFO)
    - Volume quantity calculations
    - Simply as a logical design feature (parking lot, median island, etc)
  - The Model uses a FIFO list to determine the order that Site Objects are merged so the designer has control over how side slopes intersect. The Base Object is always first.
  - DTM Feature type of Site Elements determines the Site Object triangulation (boundary vs. breakline).

Some Key Definitions…

- **Site Models**
  - Made up of unlimited number of Objects arranged according to the FIFO List.
  - Models can be modified any time in the design process
    - » Add or remove Objects
    - » Change the Base Object (modify ground tin)
    - » Change the order of Objects in the FIFO List

Roadway Network Tool

- This tool consists of six components
  - Preferences – Opens the user defined preferences for setup or editing. Preferences are also accessible from the network and create/edit tools.
  - Network – The main tool used to create the roadway network objects. It automatically loads alignments (adding them to coordinate geometry), creates a best fit design profile, computes composite sections and builds design profiles for curb returns and cul-de-sacs. And final cross-sections of the roadways are produced. Cross-sections and profiles are created in separate models for each roadway.
  - Create/edit – A wizard which allows user tweaking of the automatic design.
  - Curb Return – Allows curb returns to be designed/redesigned independent of the main network tool.
  - Cul-de-sac – Allows cul-de-sacs to be designed/redesigned independent of the main network tool.
  - Tabular data – Allows editing/adding of tabular data for profiles and cross-sections labeling. Tabular data can be automated in the network tool but can slow performance if you do so. Also, since automatic designs often need tweaking, the tabular data would be inaccurate after a single edit. This tool allows tabular data to be added after all design and tweaking is completed.

Suggested Light Reading

- Moving to Model-Based Design Autodesk Whitepaper
- True Model-Based Design with Autodesk Civil 3D Autodesk Whitepaper
- Implementation of GPS Controlled Highway Construction Equipment Alan P. Vonderohe (April 2007)
- Barrett, L., (2006), "Field Benefits Available for Wide Range of Projects", presented at the HEEP Annual Meeting, September.
- Bowman, D., (2006), "Evolving Expectations for Project Delivery to Construction", presented at the HEEP Annual Meeting, September.
- Engineering News Record, (2006), "Award of Excellence: Dwayne McAninch", McGraw Hill Construction, April 10.
- Fenton, S., (2006), "Design to Construction: A Digital Evolution", presented at the HEEP Annual Meeting, September.
- Hartzheim, P., (1990), "A Proposed Wisconsin High Precision Geodetic Network Surveyed with GPS Technology", Wisconsin Department of Transportation, September.

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- Hartzheim, P., (2006), "Wisconsin Height Modernization Program (WI-HMP): Improving the Vertical Component of the Geodetic Network", presented at the Wisconsin Society of Land Surveyors Annual Institute, January.
- Hartzheim, P., and B. Fosburgh, (1994), "Densification of High Accuracy Reference Networks (HARNs)", Point of Beginning (POB), Volume 20, Number 2.
- Kuczaj, D., (2006), "The Role of WisDOT Designers and Surveyors in the 3D Machine Control Environment", presented at the WisDOT Surveying Users' Group Meeting, February.
- McAninch, Inc., (2005), GPS Integration in Highway Design and Construction, West Des Moines, IA. Streett, D., (2006), "Business Advantages of Using 3D Technologies", presented at the HEEP Annual Meeting, September.
- Taylor, D., (2006), "GPS Machine Guidance Construction", presented at the North Carolina DOT Construction Engineers' Conference.
- Vonderohe, A., (2007), Interim Report for Implementation of GPS Controlled Highway Construction Equipment, Construction Materials and Support Center, University of Wisconsin – Madison.

Thanks!

Mid-Continent MicroStation Community

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