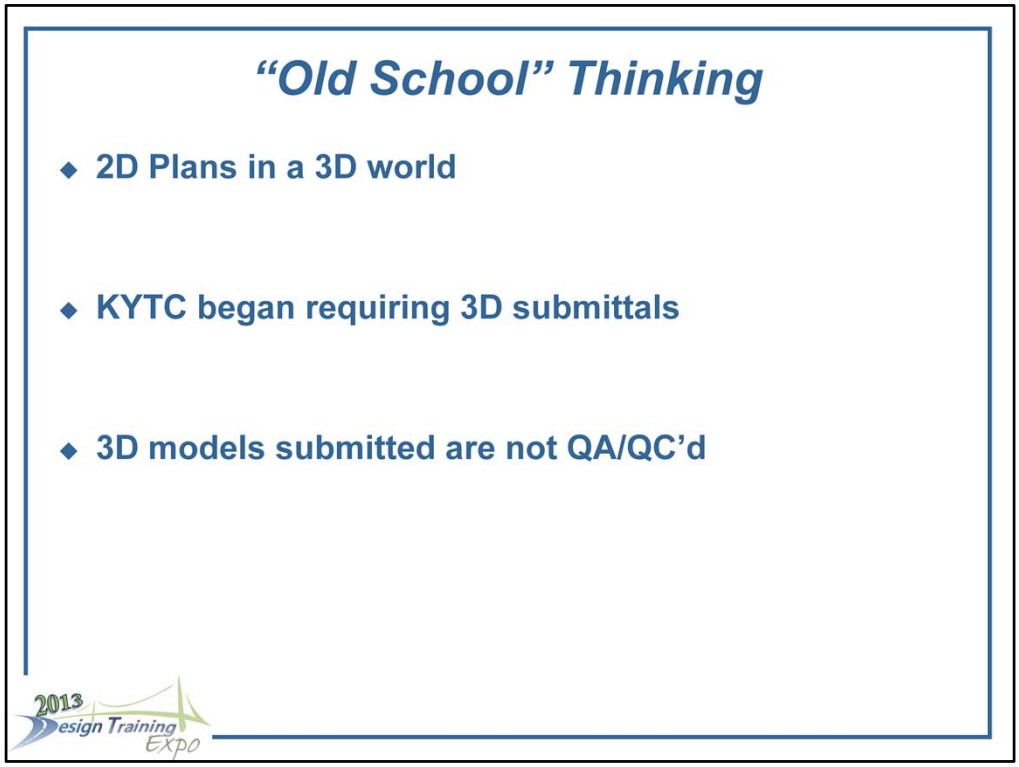
3D Engineered Models for Construction

The Kentucky Experience and Pilot 3D Model as Contract Document

Jason Littleton, PE



KYTC has, like every other state DOT, traditionally required a 2D plan set as the submittal and the legal and binding document for construction. Around 2005, KYTC begin requiring "complete" 3D models as a submittal. This required electronic data has yet to be QA/QC'd

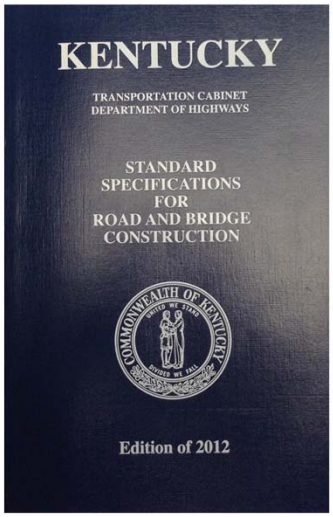
Which files are submitted?

Supplemental Information	File Format(s)	Notes
Mapping files (3D)	.DGN	Existing Manuscript
Existing Ground Digital Terrain Data	.DTM and .XML	Existing digital terrain data of project area
Coordinate Control Data	ASCII	N,E,Z of control points and PR R/W monuments
Alignment Geometry	.ALG and .XML	All centerline horizontal and vertical alignments
Superelevation Report	.XML	Data file will contain information about superelevation transitions
Proposed Roadway Model	.DTM, .ITL, .IRD, .XML	Proposed 3D model or roadway and approaches
Proposed Manuscript (3D)	.DGN	Includes existing contours and planimetrics as well as proposed features and project control points

KYTC requires its designers to submit these electronic files with their final plan submittal. We require a 3D drawing file of the existing manuscript as well as the existing ground data in InRoads DTM and LandXML format. We have determined that LandXML is a common file format that most softwares can accept. We also require a listing of all control points and right of way monuments in ASCII format. The proposed centerline information is submitted in InRoads ALG and LandXML formats along with an XML file with superelevation information. The real meat and potatoes, however, is the proposed roadway model. This is what the contractor is going to use to grade the proposed surface. We require the InRoads DTM and the LandXML of the proposed roadway as well as InRoads ITL (Template Library) and InRoads IRD (Roadway Designer) used to create this model. The designer also submits a 3D drawing file of the proposed manuscript including existing ground contours and planimetrics along with proposed features and control points.

What happens to these files?

- Contractors "reverse engineer" plans
- Documents (Sec 105.05)
  1. Questions/Answers
  2. CAP Report
  3. Special Notes
  4. Special Provisions
  5. Plans
  6. Standard Drawings
  7. Supplemental Specs
  8. Standard Specs



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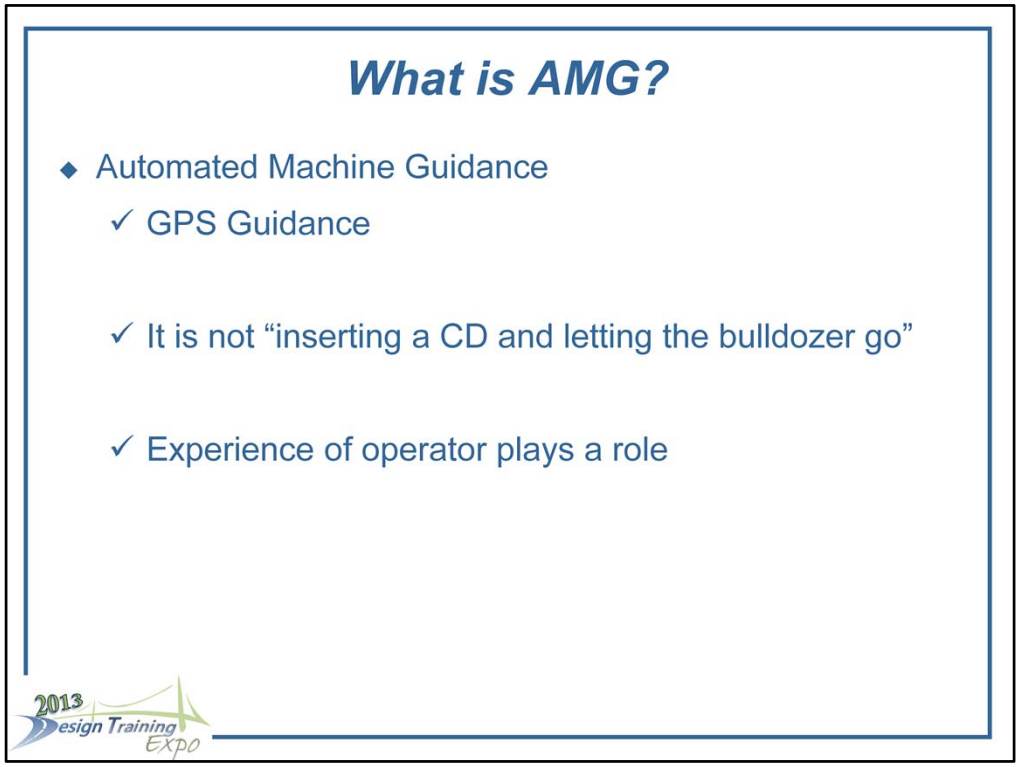
Due to the fact that the electronic submittals are not checked, often, these submittals do not match the plan set. If you remember, we said the plan set was the legal and binding document for construction. Therefore, the contractor will often give the plans to a 3rd party to create a model that is useful with Automated Machine Guidance. With our electronic data, a disclaimer is include that the data is "FOR INFORMATION PURPOSES ONLY". Also, in the KY Spec book, the 3D model is NOT listed in the hierarchy of project documents.



AMG stands for Automated Machine Guidance. GPS units are mounted to construction equipment to help guide the blades, etc to make the proper cuts. AMG IS NOT inserting a CD and letting the machine go! The Texas Department of Transportation, in their discussions with their contractors association, noted that their contractors thought by having a model that anyone could drive a machine with little training and experience. They found that the more experienced operators did an extremely better job because they could recognize problems and adjust on the fly and not blindly follow a model.

What is AMG?

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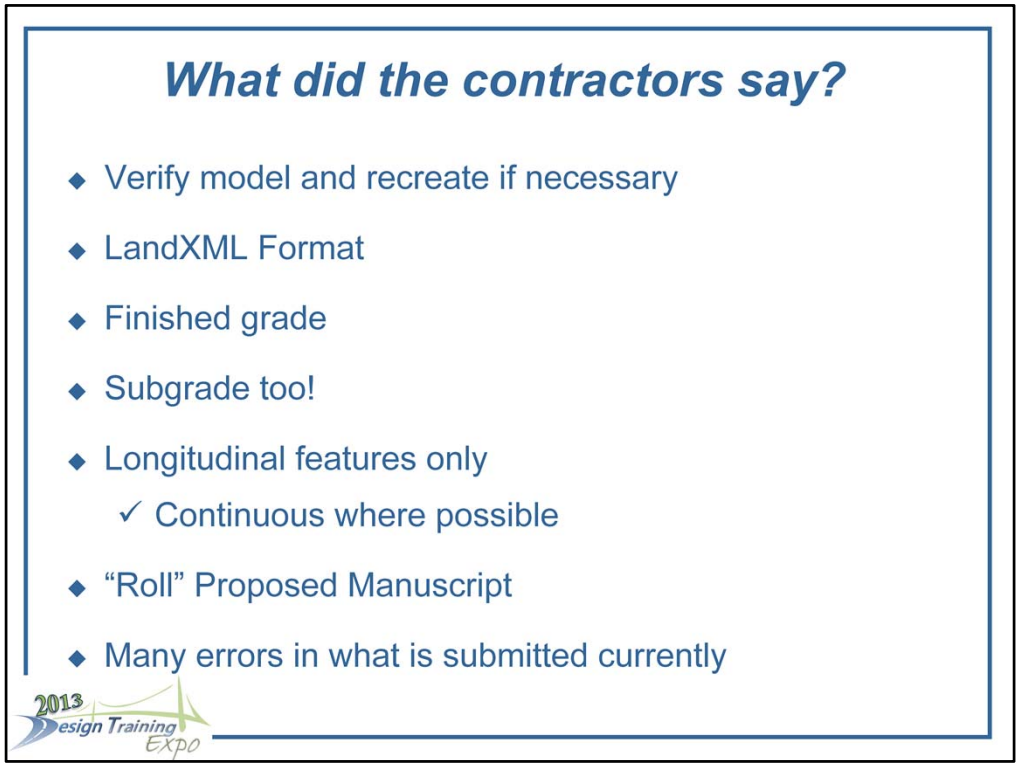
In June 2011, the decision was made to use an “in-house” design project as a pilot for use with this not-so-new technology. The project was selected because it was determined to be a good candidate and it was being designed in house giving KYTC more flexibility to try new things. A meeting with the KY Association of Highway Contractors was also held to determine their thoughts on the proposal and to gather their input as a starting point.



When the contractors were asked how they were checking the model they responded that they would display, in a 3rd party software, the proposed 3D model on the provided cross sections. If they did not match, then the model was of no use to them since the plans are the legal and binding document. At this point, they would pay a 3rd party to recreate the model from the paper plans.

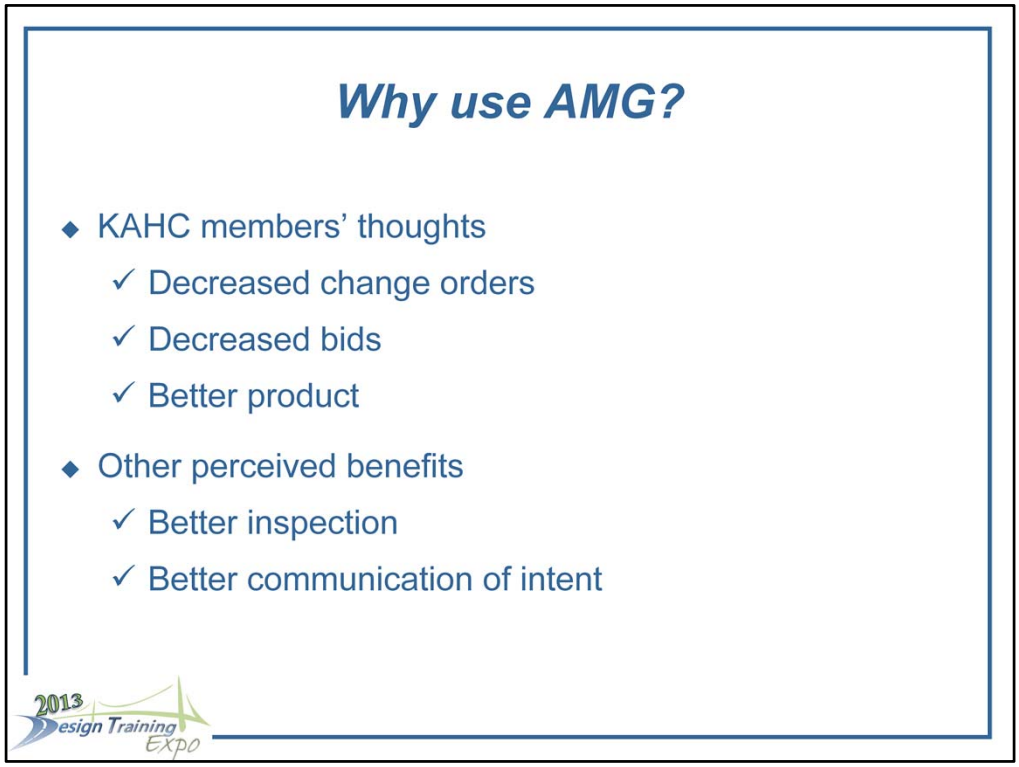
The contractors were also asked what formats for the proposed models the software they use could handle. A very wide variety of answers were given, but the one constant was the LandXML format. This format, luckily, is one that KYTC can export from InRoads.

The overwhelming request of the contractors present was that the proposed model match the provided cross sections. If they can see that they match then using our model would not be an issue. They also mentioned that having a subgrade (or top of dirt) surface provided would be quite helpful.

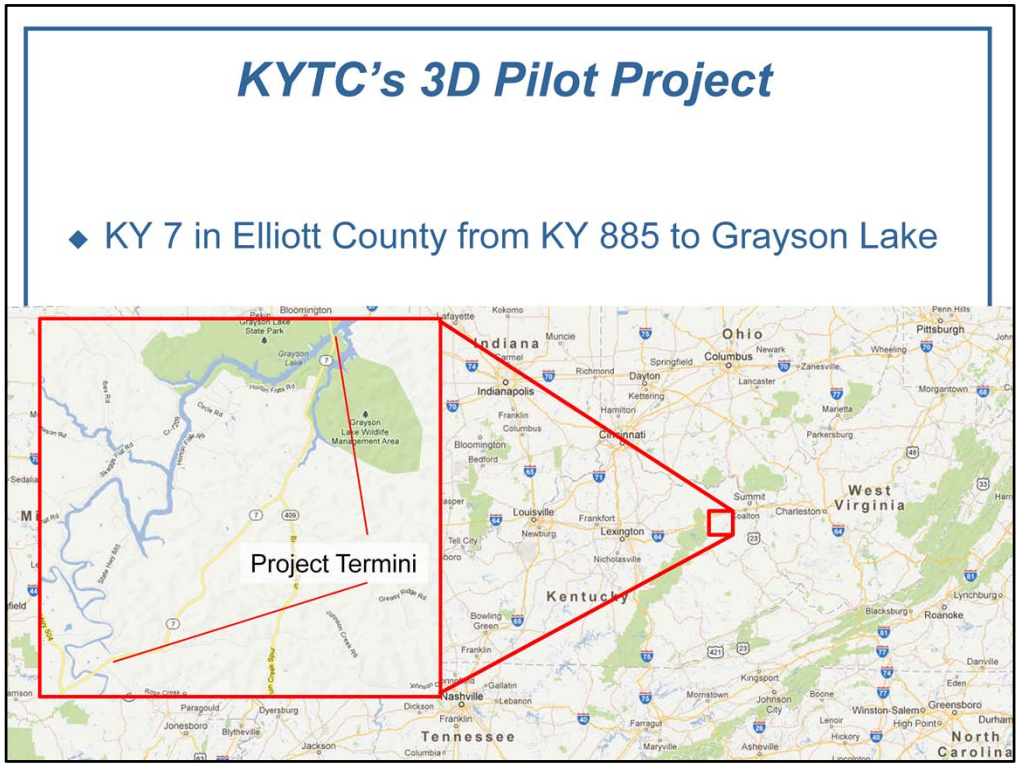
Obviously, some models for longer projects can get quite large in file size. And the equipment available to the contractors can only handle so much data. To try to reduce the file size without diminishing the value of the model, the contractors suggested providing only longitudinal features (EPs, CLs, SHs, etc.) and leaving out the transverse features and triangles. The transverse features and triangles do not add much more integrity for the amount of data it adds. The longitudinal features need to be as continuous as possible. When a breakline ends, the equipment does not know what to do from that point.

The contractors were also wanting to have the proposed manuscript with all EPs, CLs, SHs, ditches, pipes, limits, etc all in one file; like a roll rather than in individual plan sheets.

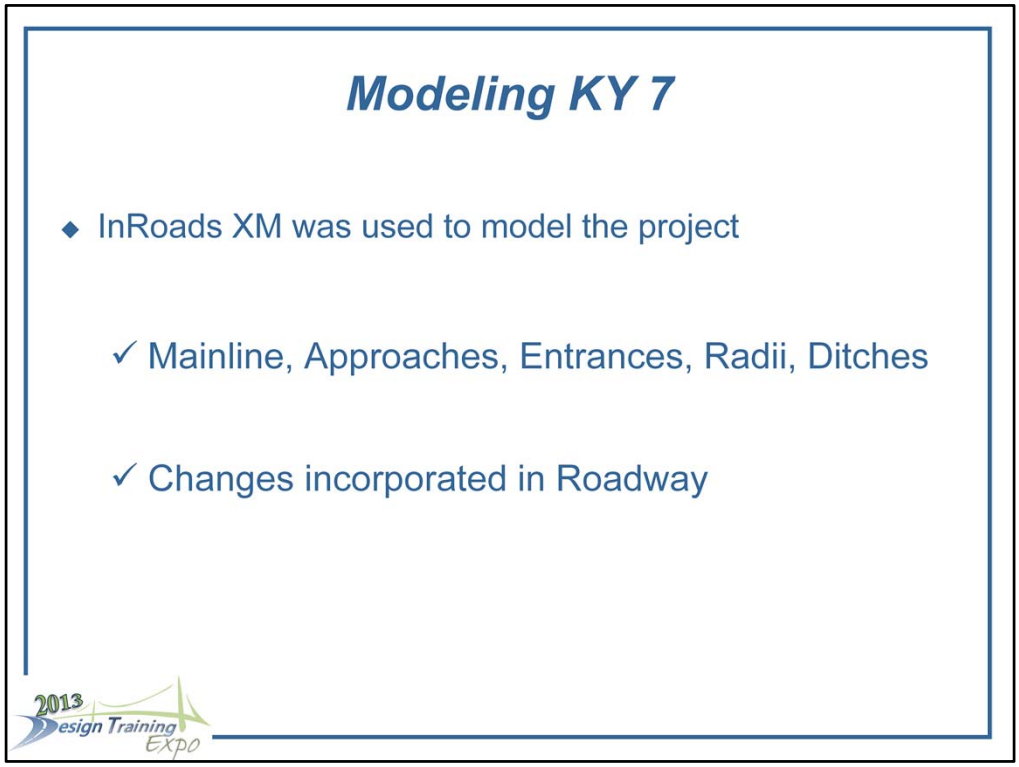
They also mentioned that the quality of the current submittals is severely lacking. Not only in the model but also in the plan set in general. In the model in particular, they mentioned that it is not unusual to have up to 20' busts through intersections.



So what are the benefits of having giving contractors information to use with AMG? The KY Association of Highway Contractors members present at our meeting suggested that some benefits to be reaped from this would be decrease bids and change orders as well as providing a better product to the taxpayers. Other perceived benefits could include better inspection of the construction. Also, better communication of design intent. Contractors work in a 3D world; why shouldn't designers?



The project selected to be used as KYTC's pilot is in located in Elliott County, KY in eastern Kentucky. It is approximately 5 miles of rural, 2-lane road relocation of KY 7 just north of Sandy Hook. The majority of this project is located off existing alignment. It has approximately 3 million CY of excavation. A KYTC surveyor confirmed the project had good GPS coverage for use with AMG.



Models for mainline KY 7 as well as all 65 approaches and entrances were created along with models for the radii, especially the radii, rather than just draw the radius in plan view. Both surface and cut ditches were modeled as well. Understandably, there were changes along the way. "Old School" thinking would have the designer making these changes in the cross sections. At this point the plans are no longer an accurate representation of the model. Instead, KYTC designers made these changes in the Roadway Designer file so that they would be reflected in the model. This was an iterative process. The time spent on editing cross sections was instead devoted to editing the model such that the cross sections would not need to be edited.

There were many meetings along the way, one of which was with the Divison on Construction and the State Highway Engineer's Office. In this meeting goals for the project were presented.

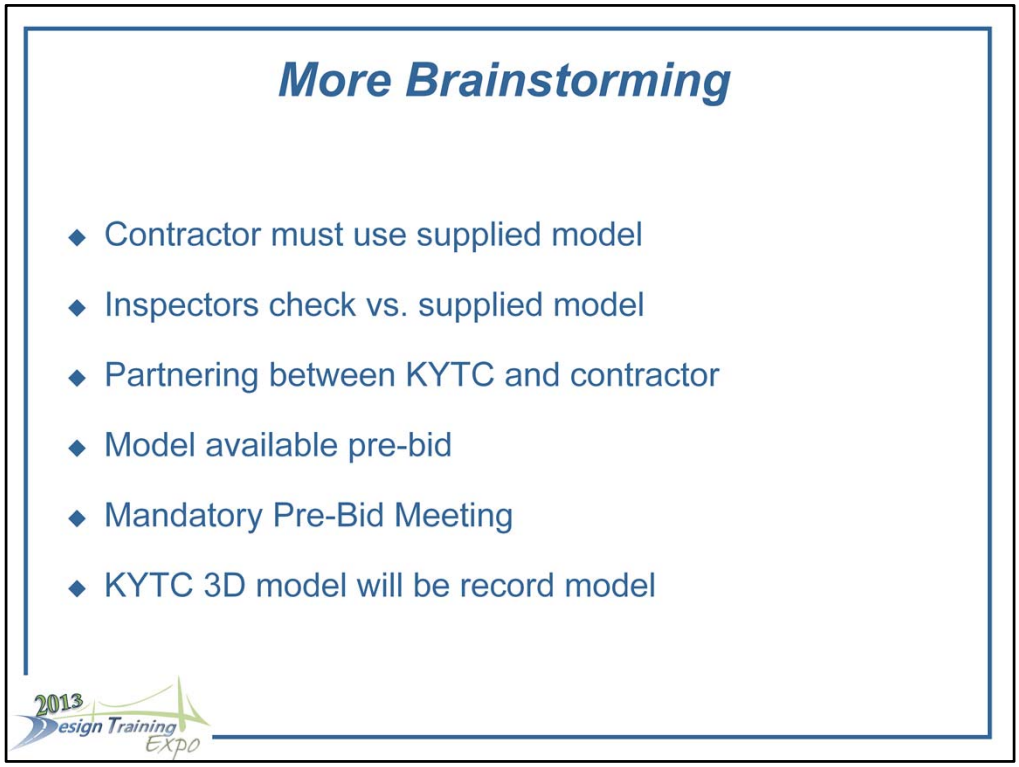
1. A Best Modeling Practice was desired to give designers a starting point to create better models on future projects.

2. The issue of getting the contractor the design model needed to be resolved. Our second goal was to determine the most efficient way to give the contractor our model.

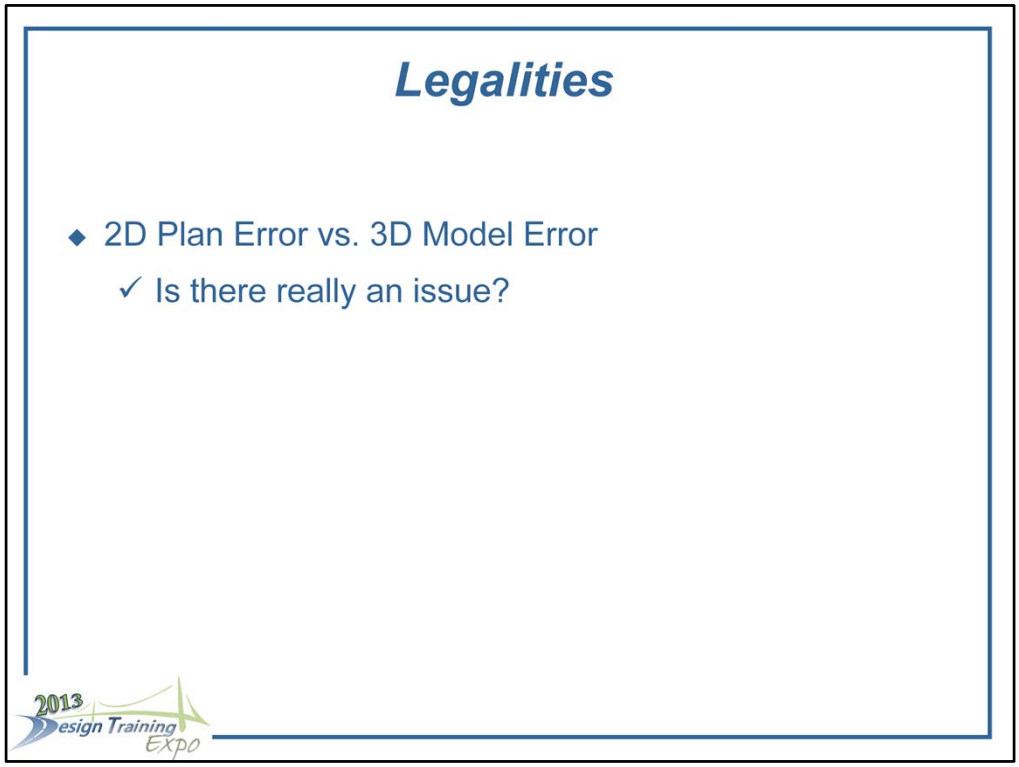
3. Traditionally, once the project has been let, the designer is done. With the implementation of AMG and more specifically with contractors using KYTC models, the designer's role is unknown. That role needed to be defined through this process as well.

4. Historically, Construction and Design have very little communication. With this project, we hope to promote better communication between all parties.

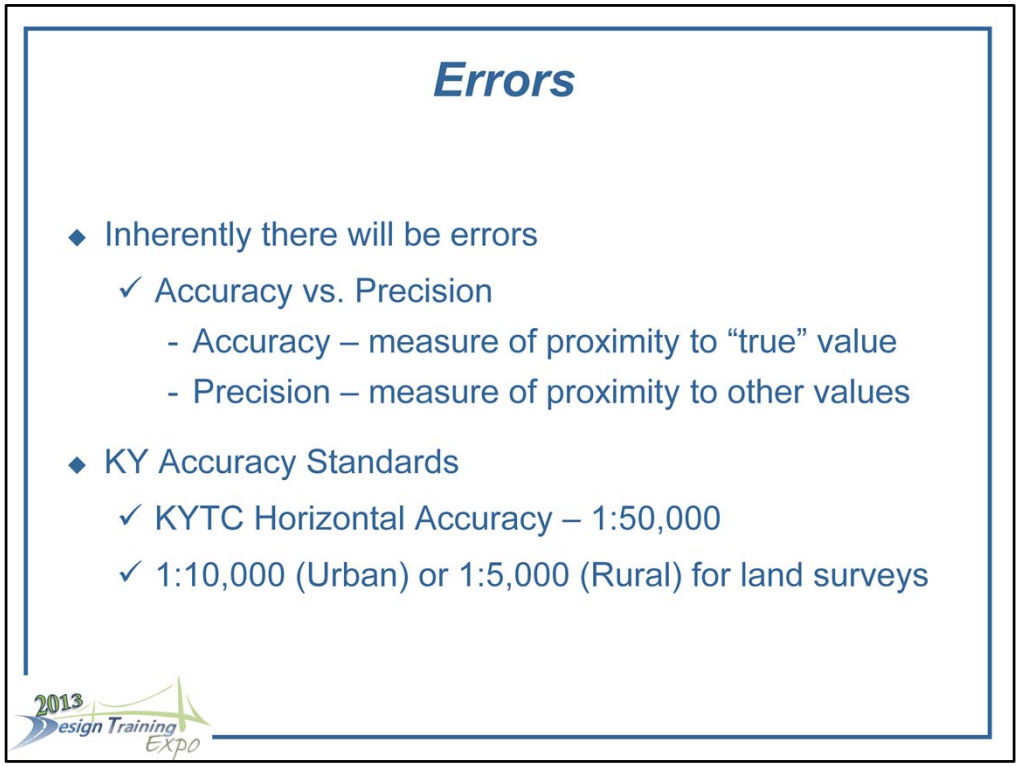
5. Ultimately, we would like to revise our electronic submittal policy to encourage the submittal of better 3D models.



Some other ideas coming from this meeting were that the contractor must use the model as supplied by KYTC. To help encourage the use of KYTC's 3D model, we are requiring our inspectors to check the contractor's work against the supplied 3D model. We know that we are, in effect, building the plane as we are flying it. As such, we need to have some form of partnering between KYTC and the contractor. We need the feedback from the contractor to refine our process for the future. We understood that if the contractor would be required to use our 3D model then we should allow them to have access to the model before bidding. Also, as this is a first in the state of Kentucky, we made mandatory that each contractor and subcontractor be present at a pre-bid meeting in order to submit a bid for the project. To further encourage use on the supplied 3D surface model, it was suggested that the 3D model supplied by KYTC should be the record document.

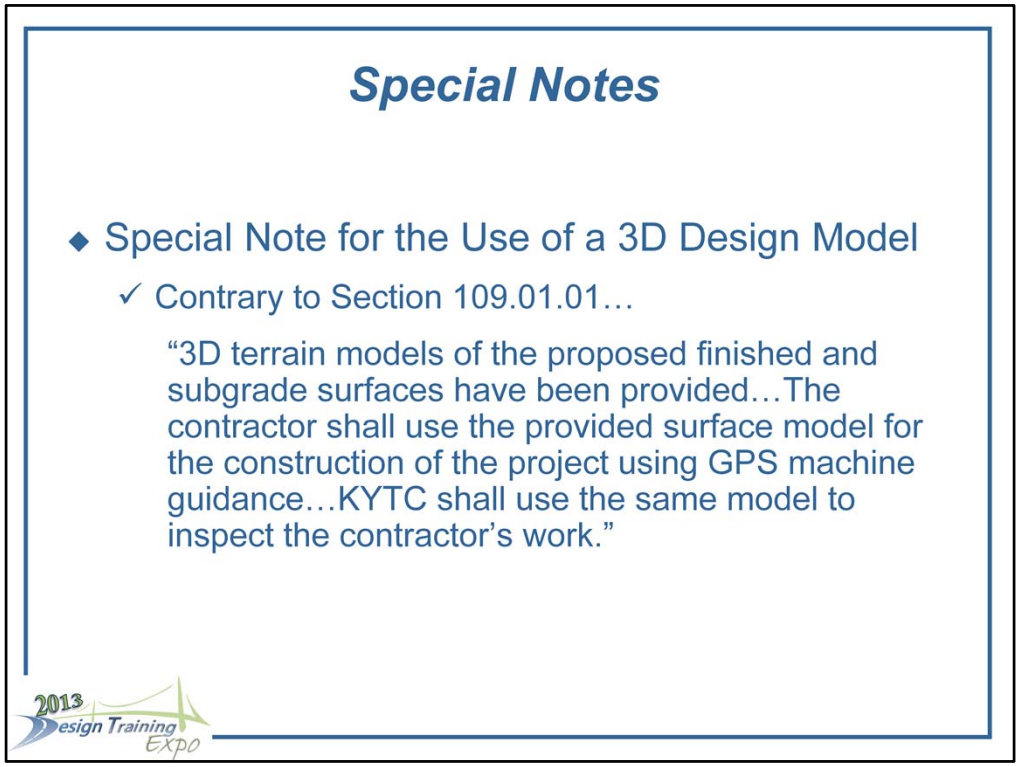


There are errors in 2D plan sets just as there are errors in the 3D surface models. But is this really an issue? Our staff attorneys seemed to think not. With every project we send to construction there are errors. We have been “handling” these errors for decades through agreements and change orders. As mentioned before, one of the goals of this process is to decrease the number and severity of change orders. There will still be and will always be errors but we want to minimize these.

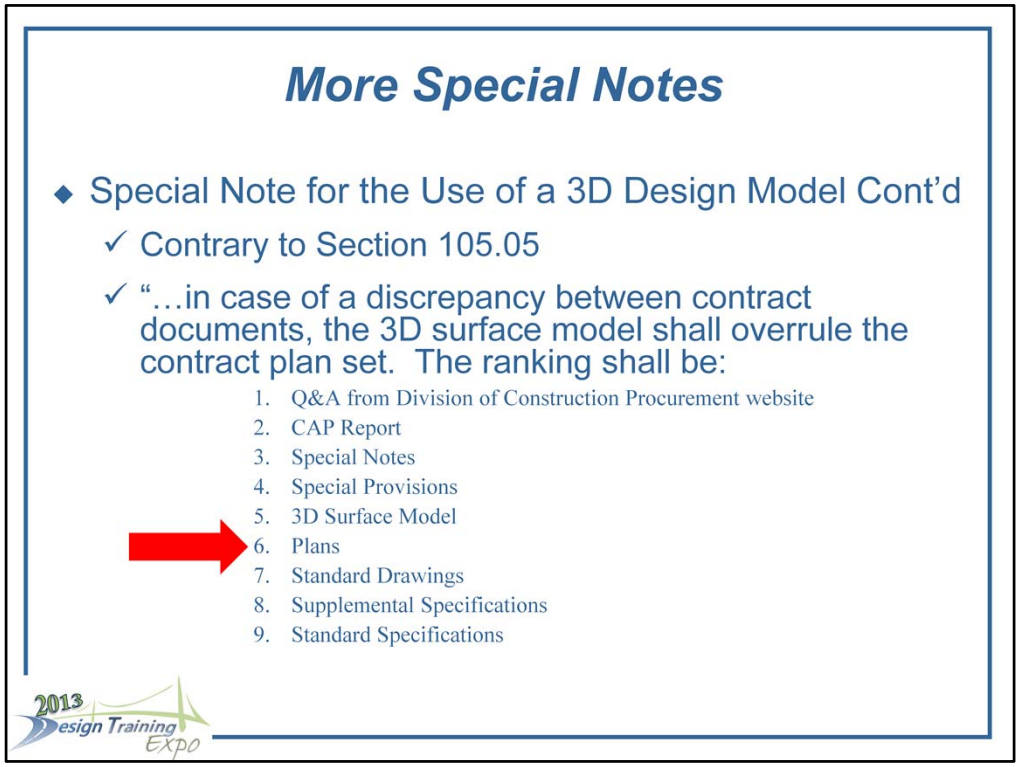


There will be errors in the 3D model just as there are errors in the 2D plan set. We do not live in a perfect world; there is error in everything we do. And we must accept some error as reasonable. We need to remember that this information is for use on bulldozers and graders outfitted with GPS. Do we need to be accurate or precise? Accuracy is a measure of how close to the actual value desired—the true value. Precision is a measure of repeatability—how close the "readings" are to one another. Another way to think of accuracy and precision is in terms of random and systematic errors. Errors of accuracy would be random errors and errors of precision would be systematic errors. In regard to the 3D model, we need the model to be accurate; but there is a point of diminishing return where the increased accuracy is not worth the time and money investment.

Land surveyors deal with errors everyday and accept them within reason. For boundary surveys in Kentucky, the traverse used to set the property corners must "close" with an accuracy of 1:10,000 in urban areas or 1:5,000 in rural areas—meaning they must "close" within 1 foot of the start point for every 10,000 feet or 5,000 feet of traverse. The Kentucky Transportation Cabinet has more stringent requirements for roadway surveys; the traverse used to set primary control for the project must "close" with an accuracy of 1:50,000. We accept reasonable error in other venues and we should with 3D surface models as well.



Special notes were used to override the KY Standard Specifications. Section 109.01.01 covers the general measurement of quantities. We used this verbiage to let the contractor know that the inspectors on site will be checking their work against the supplied model.

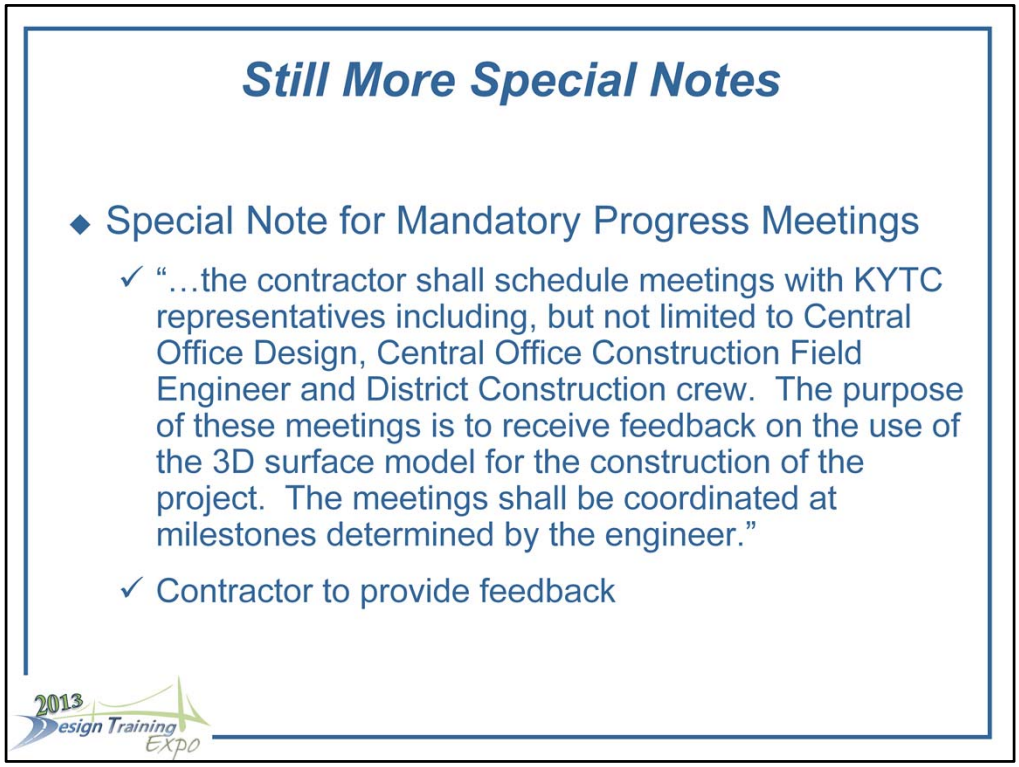


Section 105.05 of the KY Standard Specifications address the coordination of contract documents. To show the contractors the confidence we felt with the 3D proposed model, and hopefully instill in them some confidence in us, we inserted the 3D Surface Model above the Plans in order of precedence.

Even More Special Notes

- Special Note for Corrections to 3D Surface Model
  - ✓ "Any changes to the initial 3D surface model due to errors or omissions shall require a minimum of 72 hours to complete at the discretion on KYTC. All requests…shall be sent to the Engineer, who will coordinate with the Division of Highway Design to investigate and correct.
  - ✓ "Any value engineering proposal that requires edits to the initially furnished 3D surface model shall be processed within 5 working days after the Cabinet approves the requested VE proposal."

Inevitably, there will be errors in the 3D model. For this reason, we included a special note to address this issue. KYTC will have at least three days to correct any errors and omissions once they are found. Also, the contractor may provide value engineering suggestions to decrease the cost of the project. If this VE proposal is accepted, the contractor splits the savings with the Cabinet. These types of changes would likely be more significant than would an error or omission correction. Therefore, we stated that KYTC will have 5 days to adjust the model for the VE changes AFTER approval of the proposal.

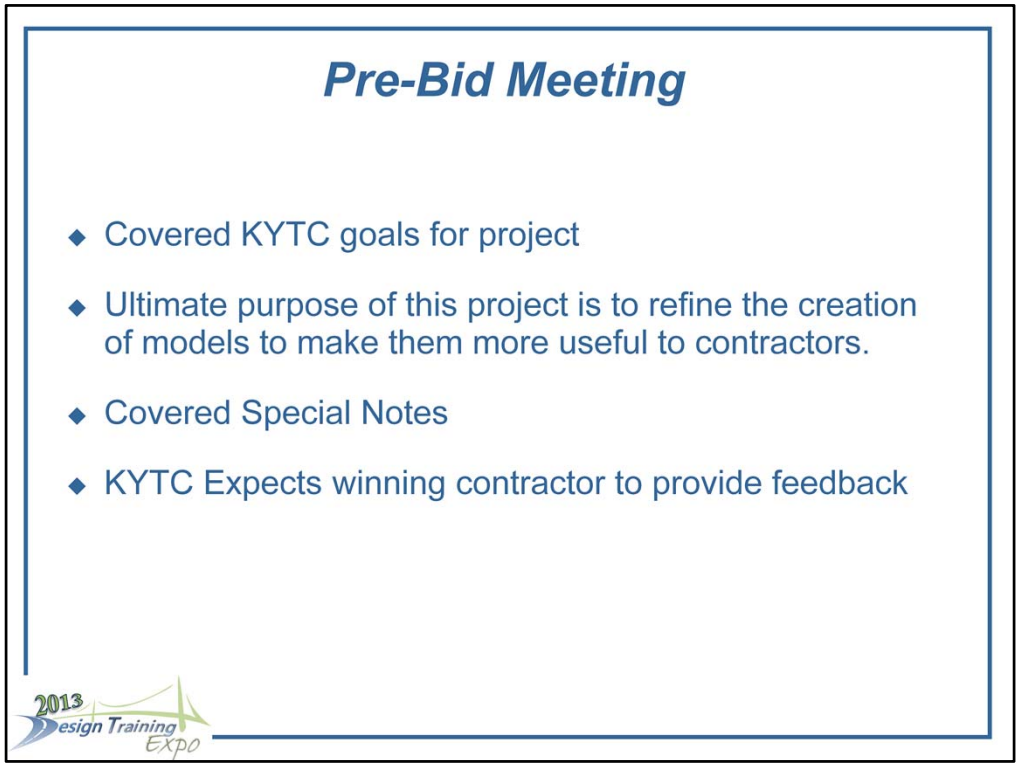


With this being a pilot project, we recognize that this will be a learning experience. We want feedback from the contractor whether it is good or bad. We need to know where we are excelling and where we are falling short. If this is the direction we intend to go, then we need to refine our process and the only way to do that is through the feedback we receive. We put a special note in the plans to require the contractor to meet with the designers to give both sides a time to ask questions and comment on the process. We have not had any meetings at this point, but are hopeful that with the feedback we receive we can apply that to other projects to learn more before requiring all designers to supply a detailed proposed 3D model for AMG.

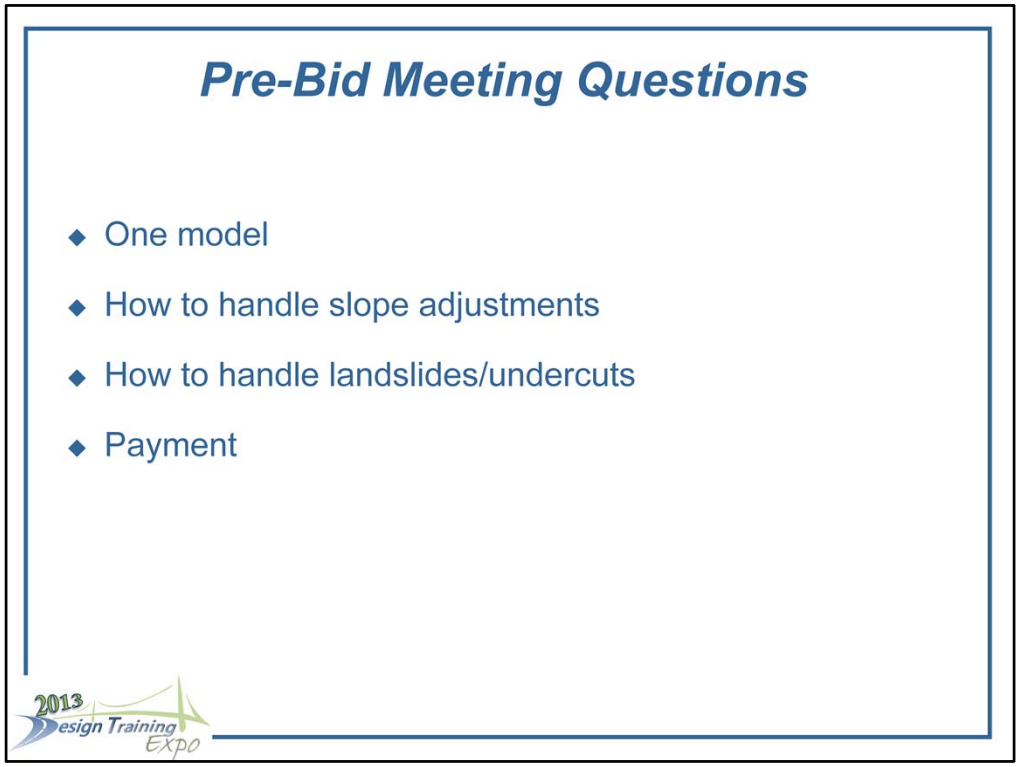
Lots of Special Notes

- Special Note for Earthwork Quantity Calculation
  - ✓ Contrary to Section 204.04.02
  - ✓ "Earthwork quantities were calculated using InRoads triangle volumes instead of end-area volumes from cross sections…Major errors are defined as individual mistakes of 3 percent of more in quantity of earthwork between two consecutive cross sections as shown on the earthwork volumes sheets

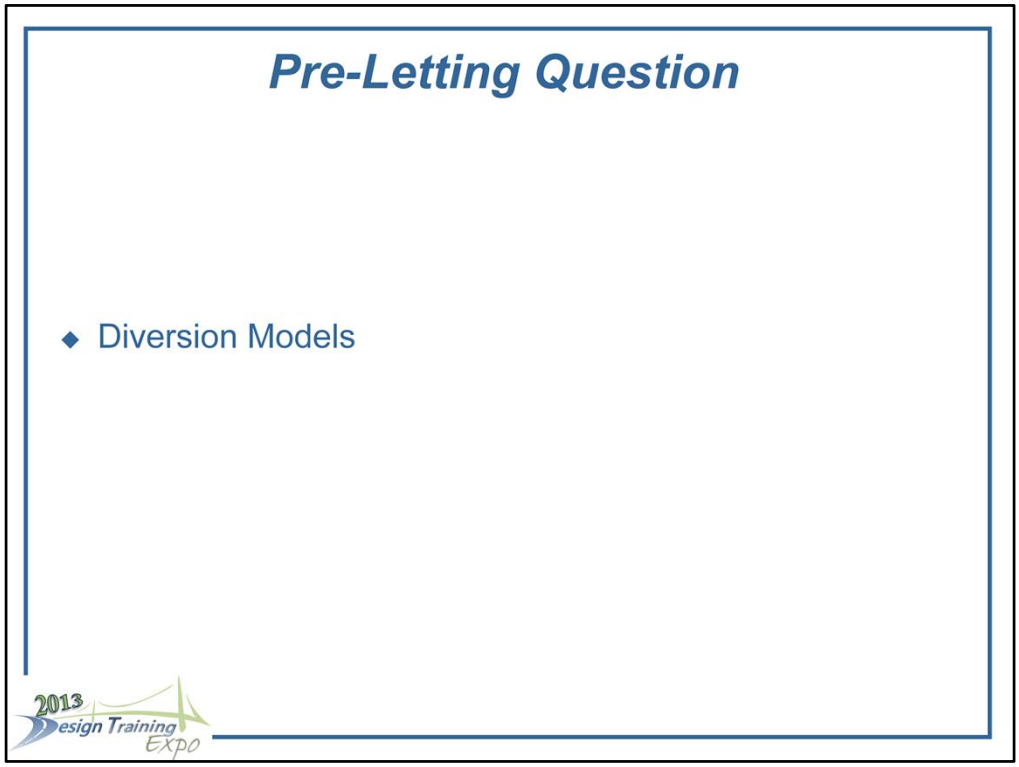
Section 204.04.02 deals with Authorized Adjustments. Instead of using the end-area volume method to calculate volumes, we let InRoads calculate volumes between the two surfaces. When we proposed this to Construction personnel, they were concerned with not having volumes between each cross section. InRoads allowed us to report volumes between each station in tabular format. No volumes were shown on the cross sections, but rather tabled at the end of the cross sections.



At the mandatory pre-bid meeting the goals of KYTC for this pilot project were covered. The ultimate purpose of this project is to refine the model creation process such that the supplied 3D model is more useful for the contractor. KYTC made it a point to cover all special notes and expectation. The main expectation of the winning contractor is to provide feedback to help refine the modeling process.



During the pre-bid meeting, one surface model, incorporating all approaches and entrances was requested. KYTC responded that one surface model will not be made available for this project, but this will be taken into consideration for future projects. The contractors present were also concerned about how to handle fill slope adjustments made to waste material. It was determined that these adjustments would be submitted to the designer to correct in the model and send back to the contractor. Occasionally, landslides occur and occasionally the contractor needs to undercut to remove unsuitable material. They wanted to know how payment for this would be handled with this pilot. For these instances, KYTC will pay for this per the Standard Specifications. They also wanted to know is KYTC would pay the plan quantities; these are also handle per Standard Specification.



In the hierarchy of contract documents, the first one is Questions and Answers for the Division of Construction Procurement website. One question submitted leading up to the letting concerned the availability of model for the diversions. The designer responded that the winning contractor will be given the horizontal and vertical alignment for each diversion, however, no models will be provided.

Currently, we are awaiting US Army Corp of Engineers permit for this project. As such, work has not commenced to date.

Knowing what we know now, KYTC would like to apply the lessons learned from this first pilot project on a second project to continue to refine our process. Ultimately, the policy for electronic submittals will need to be revised to include more emphasis on truly complete 3D models. To aid designers with the transition to more complete models, KYTC plans to develop a Best Modeling Practice for AMG. This may include tips and tricks, rules of thumb or even short classes to help designers model for machine guidance. Inevitably, AMG will not be feasible for every project. This does not mean that proper modeling for each project is not important, but rather that it may not be advantageous for the contractor to utilize AMG on say a small bridge replacement. As such, we need to develop guideline on when to model specifically for AMG.

QUESTIONS???

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THANK YOU!!!

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