TECHBRIEF

U.S. Department of Transportation
Federal Highway Administration

Automated Machine Guidance with Use of 3D Models

CASE STUDY • SPRING 2014

THE USE OF AUTOMATED MACHINE GUIDANCE ON THE FLORIDA SR 417 LANE WIDENING PROJECT

ABSTRACT

Automated machine guidance, or AMG, uses data from sources such as 3D engineered models to provide real-time horizontal and vertical location information to the operator of construction equipment during earth work and paving operations. Using AMG, the equipment adjusts automatically based upon that 3D modeling information with operator override, as needed. This technical brief is a case study of a project in Florida where the Orlando-Orange County Expressway Authority (OOCEA) used AMG to complete a lane widening project. Both the contractor and OOCEA learned some valuable lessons from this initial 3D engineered model and AMG/AMC project.

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BACKGROUND

During 2012, the OOCEA undertook a project to widen a stretch of SR 417 on the Orlando–Orange County Expressway. The project area was 4.1 miles long and improved the section from two lanes in each direction to three through lanes and one full length auxiliary lane in each direction. In order to accomplish this project, the profile and cross-slope needed to be modified, in some places significantly. The original design was created to economize the asset for the Orlando–Orange County Expressway Authority; however, this approach meant inherent construction inefficiencies due to the quantity of milling control points and many problematic transitions.

THE PROJECT

While examining the milling control plans for this project, the contractor and the construction engineering inspector discovered that the milling control point transitions were going to affect the phasing of the paving operations. In all there were 43 milling control point transitions on the southbound lanes (12 inside to outside) and 46 on the northbound lanes (11 inside to outside). The real challenges, however, were the transitions from the outside lane line to the inside lane line due to the impossibility of maintaining a continuous milling and paving operation through those transitions.

The result would limit nightly production, introduce opportunities for errors, increase the number of joints, and make tracking and payment more difficult. Furthermore, the design was based on standard construction practice of fixed depth milling combined with the use of overbuild asphalt to accomplish the profile and cross-slope corrections. Based on this approach, the anticipated overbuild asphalt quantity was 8,200 tons. At $61.50 per ton of asphalt, that would have cost owner about $504,000.

THE PROCESS

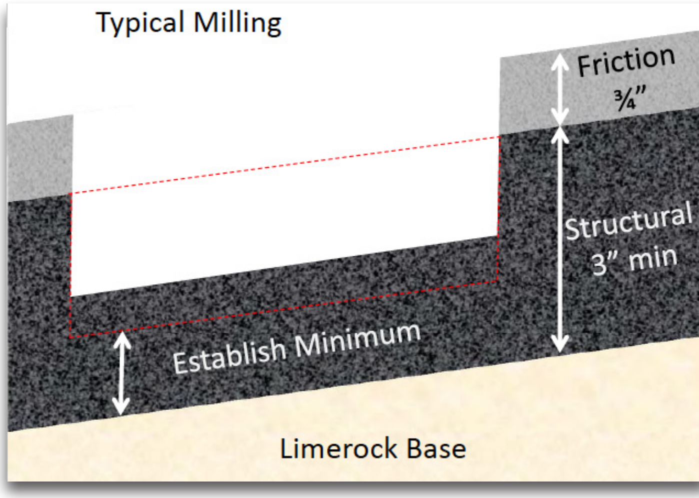
Based on these concerns, the owner proposed that the contractor consider using AMG. Upon further study, it was found that overbuild could be reduced by nearly half. This potential savings provided the impetus for an agreement, and the Design-Build contract was modified to allow for AMG to be used. Contract changes included:

- Replacing the standard specification section with a modified version that put the focus more on achieving certain elevation than certain depth.
- Replacing the fixed depth milling pay items with variable depth milling items.
- Agreeing that the milling and paving would be set to specific grades that would be established cooperatively with the model developed by the contractor and submitted for approval like a shop drawing.
- Developing a model of the proposed surface.

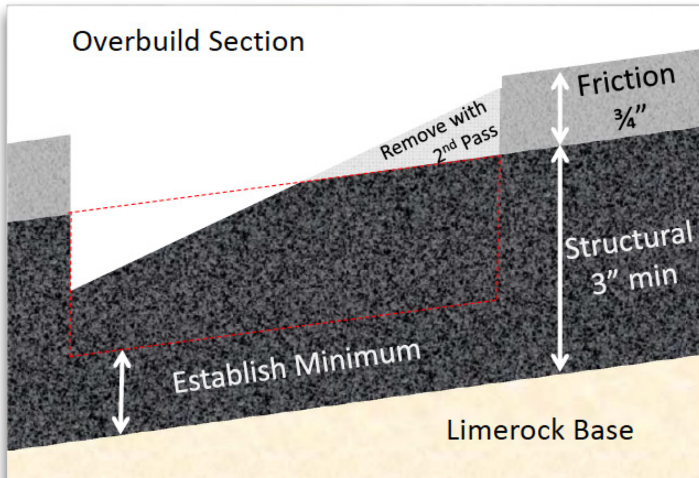
The model is a necessary component of the AMG approach. When using a model, the contractor is no longer building from the existing roadway, he is building to the proposed surface. For the purpose of estimating quantities and planning for phased construction, it is important to know the elevation of the existing surface. For this project, the elevations were collected at 25' increments along all the lane lines.

Initially the existing pavement was modeled, and then the proposed pavement was modeled with any known deficiencies being addressed during the modeling process. The model data were then exported into a table to compare the cuts and fills. This was an iterative process because if an issue was identified, the models would have to be adjusted and the comparison process would have to be repeated until the final model met all the needs of the project. Potential issues could include tie ins at ramps, bridges, existing guardrails, and drainage structures.

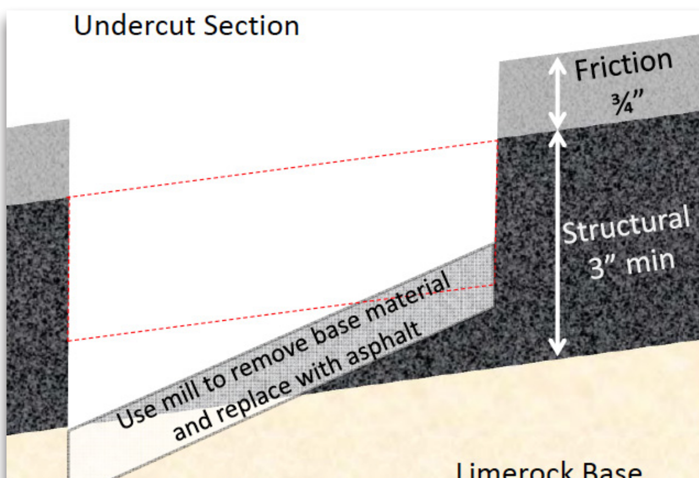
In this project, the purpose of the AMG was to correct (smooth) the existing poor profile, which required that the elevation of the pavement be changed. The second reason to scrutinize the model thoroughly is to economize the profile; i.e., to reduce the height and length of the fill sections. For this project, each portion of the model only needed 2 or 3 iterations, a process that took only days between each version.



Once the modeling process was complete, the final version was simply loaded onto a thumb drive and uploaded into the control box on the milling machine. The secondary receiving stations were then set up and calibrated prior to initiating the work. The system used for the Florida project allowed for the addition of a rover, but other secondary systems are also appropriate to confirm that proper elevations are achieved.



Two types of secondary systems are typically used in AMG. The first is based on total stations to guide the equipment, while the other is based on a laser base station. The laser base station allows for the use of multiple connections, including an elevation rover. This rover is loaded with the same model and will give the relative depth above or below the model and at any other point. For systems based on the total station concept, a total station is needed for each piece of equipment or rover used. With both systems, the base station or total station has a limited range and must be moved ahead as paving progresses.



In the Florida project, because it was a new process for many of the participants, grade markers were placed at intervals along the shoulder to confirm surveyed elevations and help boost confidence as the project progressed.

With AMG, as the milling machine moves forward, the guidance system typically adjusts the depth of the mill so that the milled surface is built to the elevations prescribed in the model. For the Florida project, the contractor and the inspectors were provided tables with the elevations so that the surface could be confirmed during construction. Because the milled surface sometimes aired out above the established level to remove the friction course, a second pass with the milling machine was needed before the asphalt paving could proceed. At that point the structural asphalt was placed in a consistent thickness lift in a second pass. The proposed thickness for the project was identical to the existing thickness, so all overbuild asphalt for this project was used to raise the profile of the road by constructing thicker pavement.

A less common scenario, but one which was encountered during this project, was for the mill to cut too much of the structural asphalt out because the automated milling machine guidance factors in elevation only. When the milling depth went beyond 2 ½", the contractor team began to core the remaining asphalt to confirm the depth. In many cases, there was enough depth remaining to proceed with the paving. There were several occasions, however, when the milling machine needed to be backed up and another 1 ½" undercut to make sure the process achieved the needed structural number.

While aspects of the process may seem counterintuitive, this is the nature of the AMG concept. When there is an existing surface with various rideability problems, the milling depth must be variable to model the pavement and build to a smooth proposed surface. In the Florida project, the basic constraints placed on the milling process were that the friction course needed to be removed and there needed to be no less than 1 ½" (out of 3 ¾" existing) of remaining asphalt after milling. To accomplish these simple tasks, the minimum milling depth was set at ¾" and pavement cores were collected any time the milling depth exceeded 2 ½". Whenever the milling depth was less than ¾", the milling operation was halted and a second pass was made to remove the friction course, which cannot be incorporated as part of the structural asphalt. At these locations, it was usually necessary to construct overbuild pavement to reach the proposed profile.

THE RESULTS

There were a number of measured benefits that resulted from using AMG to complete this project.

Ride Quality:

Because all transitions were machine guided, very few straightedge deficiencies occurred, resulting in an excellent the ride quality.

Pavement Quality:

Most asphalt was placed in uniform lifts and the overbuild pavement required was significantly reduced from an anticipated 8,200 tons to 2,500 tons, translating to a savings of more than $350,000. Where overbuild was needed, it was installed as a separate operation and the paver was equipped with AMG. This allowed the structural course to be placed with consistent lift thicknesses. The overbuild (levelling) was constructed of the same mix but in a separate operation.

Project Efficiency:

The use of models allowed the paving operations to work the length of the project in a circuit, saving time and reducing the number of lane closures required.

Safety:

With only a single MOT set up each night, safety was much greater both for workers and travelers.

Cost:

Paving operations were completed in fewer overall shifts, decreasing overhead and inspection costs and reducing delay for road users. It is possible that expenses for the contractor were incurred due to increased survey support and reduced production. The costs may have been mitigated somewhat by the near elimination of correction work.

LESSONS LEARNED

The contractor had two principal concerns when initating this project. The primary concern was that the milling machine would encounter base materials after removing all the existing asphalt. This happened at three different points during this project, but because the contractor had anticipated that this might occur, field staff were prepared to address this issue when it arose.

Another of the contractor's concerns was that the adjacent lanes would have drop-offs greater than allowable during phased construction. This issue was encountered most nights, but because this had also been foreseen by the contractor, each drop-off was addressed as planned with temporary wedging.

In conclusion, with proper planning and understanding of the potential risks or problems that may arise, delays or improper responses may be quickly and efficiently resolved.

AVAILABLE RESOURCES

National Cooperative Highway Research Program (NCHRP) Synthesis 372 Emerging Technologies for Construction Delivery, Transportation Research Board, National Research Council, Washington, D.C., 2007. http://onlinepubs.trb. org/onlinepubs/nchrp/nchrp_syn_372.pdf

Guidelines for Implementing Automated Machine Guidance, California Department of Transportation, Revised June 30th, 2009. accessed at http://www.dot.ca.gov/hq/row/landsurveys/SurveysManual/AutomatedMachineGuidanceGuidelines7_5_09.pdf

COMING SOON - NCHRP Project 10-77: Use of Automated Machine Guidance (AMG) within the Transportation Industry (expected completion 6/30/2013). http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2504

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