# New Technologies for Better Highways

New technologies are enabling roads to be built faster, smoother, and for less money.

By Richard Rybka

The year 2006 will be remembered in transportation history as a turning point in road construction. Road builders across the nation are using systems based on new technologies that enable roads to be built faster, with a smoother surface, and for less money. State by state, department of transportation officials are observing the performance of these systems and reevaluating long-standing specifications to open the road to the future.

Design of modern highways requires complex engineering. Today's new roads are carefully planned for the smooth flow of vehicles at high speed. Horizontal (route) and vertical (grade) alignments must comply with the U.S. Department of Transportation's Federal Highway Administration standards for safety. Roadway cross sections affect surface drainage and the safe speed with which a vehicle can travel along a curve. Rideability—the "feel" that a roadway imparts to the driver of a vehicle—has become a new standard for assessing and accepting road construction projects.

State DOT's are challenged with governing highway construction projects within their jurisdictions. Their mission includes ensuring that roads are built and maintained according to FHWA standards to be eligible for funding and cost-share programs.

## Traditional Construction Methodology

To ensure that roads are built as designed and meet applicable standards, state DOT's have formulated detailed specifications and provisions. These specs cover contract administration, materials, and construction methodology. They become an integral part of each contract let for road construction and bind the contractor to compliance.

*GPS-guided machine control systems automatically move the cutting edge of grading equipment to match the design grade.*

Proper subgrade preparation and the installation of road base materials have a direct and lasting impact on the quality and durability of a finished road surface. To ensure that this critical phase of road construction is properly completed, many DOT's adopt detailed specifications that cover control of materials, construction methodology, inspection procedures, and tolerances for acceptance.

These types of specifications rely on traditional methods to control horizontal and vertical alignments: wooden hubs and stakes by field surveyors at specified intervals—typically every 50 ft. Written notations on the stakes describe station (distance) and grade information for the proposed road.

During construction, grading equipment operators must interpret the stakes and translate the information into machine motions that shape the ground to the design surface. Inspectors use the stakes and hubs to verify conformance with the design at specific points. To check other areas of the roadway, they pull a stringline between stakes. Inspectors can verify the road grade at any given point by measuring down from the stringline with a folding ruler.

These traditional methods of construction control have several disadvantages. Setting grade stakes is labor intensive and time consuming, typically requiring a three-man survey crew. Layout, grade staking, and inspections represent a significant cost in a construction contract. These procedures are subject to human error.

Hubs provide "spot" elevations, or grade information, at specific points along the road. A machine operator can see that he is "on grade" at these points, but he must rely on his experience and skill to carry a smooth, continuous grade between hubs.

Subgrade preparation and leveling road base aggregates require fine grading to close tolerances, typically plus or minus one-quarter in. These operations are generally performed with a motor grader. On the average, it takes six or more years for an operator to become proficient at running these complex machines. Many areas of the country are experiencing a shortage of skilled operators. Replacements for retiring seasoned veterans are difficult to find.

## GPS Machine Control

The emerging use of GPS-guided machine control systems is having a major impact on highway construction. These systems automatically control the cutting edge of grading equipment to match the design grade. The operator only needs to steer the machine and does not need to worry about setting the blade for elevation and cross slope.

GPS-enabled machines offer several advantages over traditional construction methods for highway projects:

**Faster construction.** GPS machine control systems produce 50 percent or more increases in productivity. The time required for subgrade preparation and installation of base course materials is dramatically reduced. Design grade is achieved on the first machine pass, eliminating the time and expense of reworking areas. Operator fatigue is reduced. Projects can be completed faster and ahead of schedule.

**Smoother roads.** GPS machine control systems eliminate operator interpretation of grades and improve rideability. On a typical highway project, grade control hubs are set at 50-ft intervals. The operator can clearly see that he is "on grade" at the hub, but he must carry that grade between these points. In most instances this intermediate area will end up being low and the grade will not be continuous. These deviations can cause the repetitive bump-bump-bump syndrome experienced on highways.

Modern highway engineers may use a variety of cross sections to design for different sections of the road, including standard crowns, acceleration/deceleration lanes, ramps, and super-elevated curves. Grading transitions between different sections using hubs is difficult. These control devices only provide information at specific points. Even with an automatically controlled machine following a stringline, the operator must still stop at transitions and adjust the cross slope manually. GPS-enabled machines provide continuous grade control right through transitions, producing a smooth, uniform surface.

**Lower cost.** GPS machine control systems reduce the need for staking and grade checking. The reduction in manpower required for these tasks, as well as for inspections, results in substantial cost savings.

The economical installation of road base materials depends on an accurately prepared subgrade and careful control of thickness. GPS-enabled grading machines eliminate deviations in both cases and prevent costly overruns.

Because projects can be completed in less time, expenses for project management, field offices, temporary facilities, traffic control, detours, and other indirect costs are also significantly reduced. Improved job site safety is also important. The chance of accidental injury is greatly reduced because fewer people, performing grade setting and checking tasks, work in close proximity to actively operating machines.

## Current Status of GPS

The term "GPS" has widely been used as a general classification for products using satellite positioning technology. However, GPS implies a specific satellite system launched, maintained, and operated by the United States government. A group of satellites belonging to a specific system is referred to as a "constellation." The U.S. GPS constellation, with 24 operational satellites, is not the only constellation in existence today. Russia operates and maintains another constellation—GLONASS. This constellation currently has 17 satellites in operation, and will have 24 when fully deployed. In January 2006, The European Space Federation launched test satellites as the first step in the implementation of a third satellite constellation—Galileo. When complete, Galileo is planned for 27 operational satellites. When all three constellations are fully deployed and operable, a total of 75 satellites will be available for positioning tasks.

Satellite positioning products used in highway construction—survey rovers for layout and grade checking, and automatic grade control systems for machines—need a minimum of five satellites to operate. Currently, devices that track only the GPS constellation have access to 24 satellites. Some satellites will not be available to positioning devices due to their orbital positions around the earth. Structures and


***The accuracy of Topcon's Millimeter GPS was demonstrated on three different occasions. As a result, Georgia DOT issued a contract amendment authorizing the use of this technology.***

***Without GPS, machine operators must rely on their experience and skill at reading stakes to carry a smooth, continuous grade.***

trees may block access to other satellites. When these conditions occur, it is sometimes impossible to access the minimum number required for system operation. The result is downtime and loss of productivity.

## Leading the Way

Gary's Grading and Pipeline Company, Inc. (GGPC) is based in Monroe, GA. The company is currently working on a two-year Georgia Department of Transportation (GDOT) contract for widening US 1/SR 4 for additional lanes from I-16 to Swainsboro. Scheduled completion date is December 31, 2006. The project involves replacing 9.7 miles of old two-way roadway with a new four-lane highway. Vertical and horizontal realignments will greatly improve the traffic flow along this heavily traveled route.

GGPC started work on the project in January 2005. At the time, his crews were using conventional staking and hubbing methods to provide control for earthmoving and grading equipment. During the summer of 2005, Gary Opolka of GGPC made a decision to explore GPS technology to increase production, improve accuracy, and reduce costs.

GGPC purchased Topcon (Topcon Positioning Systems, Inc., www.topconsurvey.com) equipment from Roper Laser Company, Marietta, GA. The order included a 3D-GPS+ automatic system for a Cat 163H motor grader, a long range GPS+ base station and rover for layout, and a Millimeter GPS™/LazerZone™ system. Opolka saw an immediate need for Millimeter GPS on the US 1/SR 4 project where required subgrade tolerances are plus or minus 1/4 in.

GPS+ technology provides access to both GPS and GLONASS constellations, raising the number of available satellites to 45. GPS+ has proven successful in virtually eliminating downtime due to insufficient satellite access. Accuracy is also increased because more reference points establish a position with greater precision. To provide improved positioning performance from the future Galileo constellation, the company recently developed the G3 chip. This technology can track all signals and codes from these new satellites, as well as those from existing GPS and GLONASS satellites, and any future satellites.

Typical GPS systems used in construction applications achieve accuracies in the range of one-tenth of a foot. But GPS accuracy is variable depending on the number of available satellites, their distribution in the sky, and obstructions on the job site. This variable accuracy is acceptable for general site areas, but cannot be considered reliable when higher precision is required for highway construction. Most DOT's require a vertical tolerance of plus or minus one-quarter inch for subgrade and base course preparation.

In 2001, GDOT Standard Specification Section 300 (General Specifications for Base and Subbase Courses) was modified by a Special Provision to require the use of "... *an approved fine grading machine is required for finishing the base and subbase material supporting Portland cement concrete pavement or hot mix asphaltic concrete pavement.*"

Furthermore, specific requirements for the fine grading machine were cited. The machine must be:

- Self-propelled and track driven.
- Capable of trimming and finishing the base and subbase to the specified tolerances utilizing a rotating cutter head in front of a strike-off screed.
- Span at least one lane width and is controlled automatically by direct contact with a string line or a combination of string line and existing pavement as appropriate.

Fine grading machines are also called trimmers. This category of specialized grading equipment became popular in the 1960s. Capable of fine grading wide areas in a single pass, they brought a new level of control to subgrade preparation. Subsequent advances in machine control systems enabled stringline tracking with sonic sensors and precise hydraulic control of the cutting edge.

While trimmers were a great improvement in their day, they suffer from drawbacks. Setting stringlines is subject to human error. When transitions between super-elevated and standard crown road sections occur, the machine operator must adjust the cross slope manually. Trimmers cannot produce the results needed for today's intricately-designed high-speed roadways.

## Performance Supports GPS

Working with Bill Roper Jr., owner of Roper Laser, Opolka gathered information about Millimeter GPS and presented it to GDOT engineers. He requested that he be allowed to use Topcon's system instead of the fine grading machine required by contract provisions. On three separate days, Opolka demonstrated the accuracy of Millimeter GPS to GDOT personnel. After fine grading 400- to 500-ft long sections with the system, he set up stringlines to check the performance.

The results were impressive. "We didn't only do a stringline left to right like you would normally check grades," Opolka said. "We did an X-pattern, we criss-crossed it, we did it every way you could string it—and it was dead on the money no matter how you did it."

Subsequently, a contract amendment allowing the requested change was issued to GGPC. Based on the accurate performance observed during the demonstrations, hubs and stakes are now set 200 ft apart instead of 50 ft apart as cited in the Standard Specifications.

By the second week of January 2006, GGPC had completed half of the project. Other than wet weather that complicated crossing several creek bottoms, progress has been steady. Millimeter GPS is exceeding the expectations of GGPC and the GDOT engineers who are watching the project closely.

Mark Stancil, grading foreman for GGPC, gave an example of how Millimeter GPS is improving rideability. "You can ride the other bypass—the next ten miles north of here," he said. "It was graded with a trimmer. It's just humps, and dips, and dives. You can ride the base course on this road—it doesn't even have a finished surface yet—and it's ten times smoother than the old bypass up there."

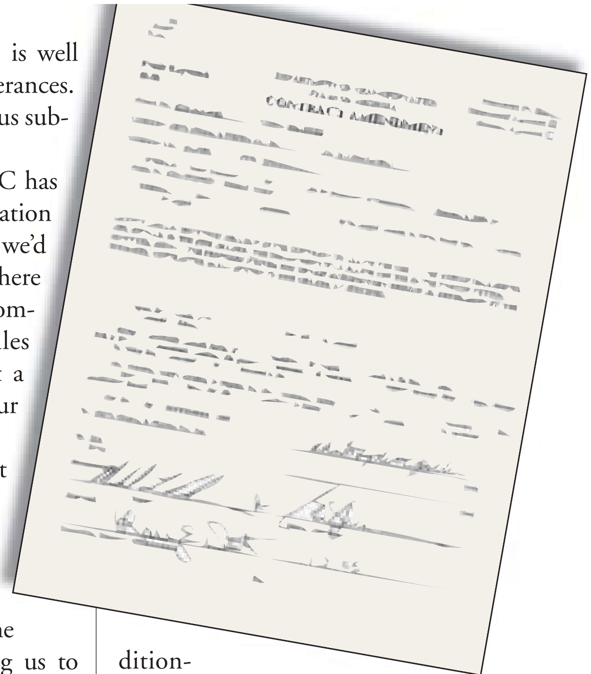
The 3D system with Millimeter GPS automatically controls the motor grader's cutting edge to within a few millimeters of design grade, which is well within the specified GDOT tolerances. The result is a smooth, continuous subgrade even through transitions.

Using Millimeter GPS, GGPC has been able to cut subgrade preparation time in half. "Without GPS, we'd probably only be half way to where we are right now," Stancil commented. "We've got two miles paved. We'd probably have just a mile without it. It doubles our productivity."

Stancil further explained that using GPS is saving money. "When we started the project, he said, "we had to have a stake and a hub every 50 feet throughout the job. Since we've changed to the Millimeter GPS, they're allowing us to put a stake and a hub every 200 feet, just where they still have something to check it by. We've cut out over half of the stakes." Since GDOT is paying an independent consultant to inspect the project, the cost of grade checking will be substantially reduced.

Based on the current satisfactory performance of the Millimeter GPS system, it is likely that GPS-enabled graders will be allowed in place of trimmers on future GDOT projects.

The case study of GGPC and the Georgia DOT is a well-documented example of how new technologies for highway construction are changing tra-


CONTRACT AMENDMENT

ditional control methods. Similar situations are taking place in many other states. Day by day, transportation officials are learning more about the benefits these new systems offer and observing the new level of performance they produce.

The real beneficiaries are the people who use our nation's roads on a daily basis. The future for our highway system is bright. We can look forward to better roads, faster construction, and lower cost. GE

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