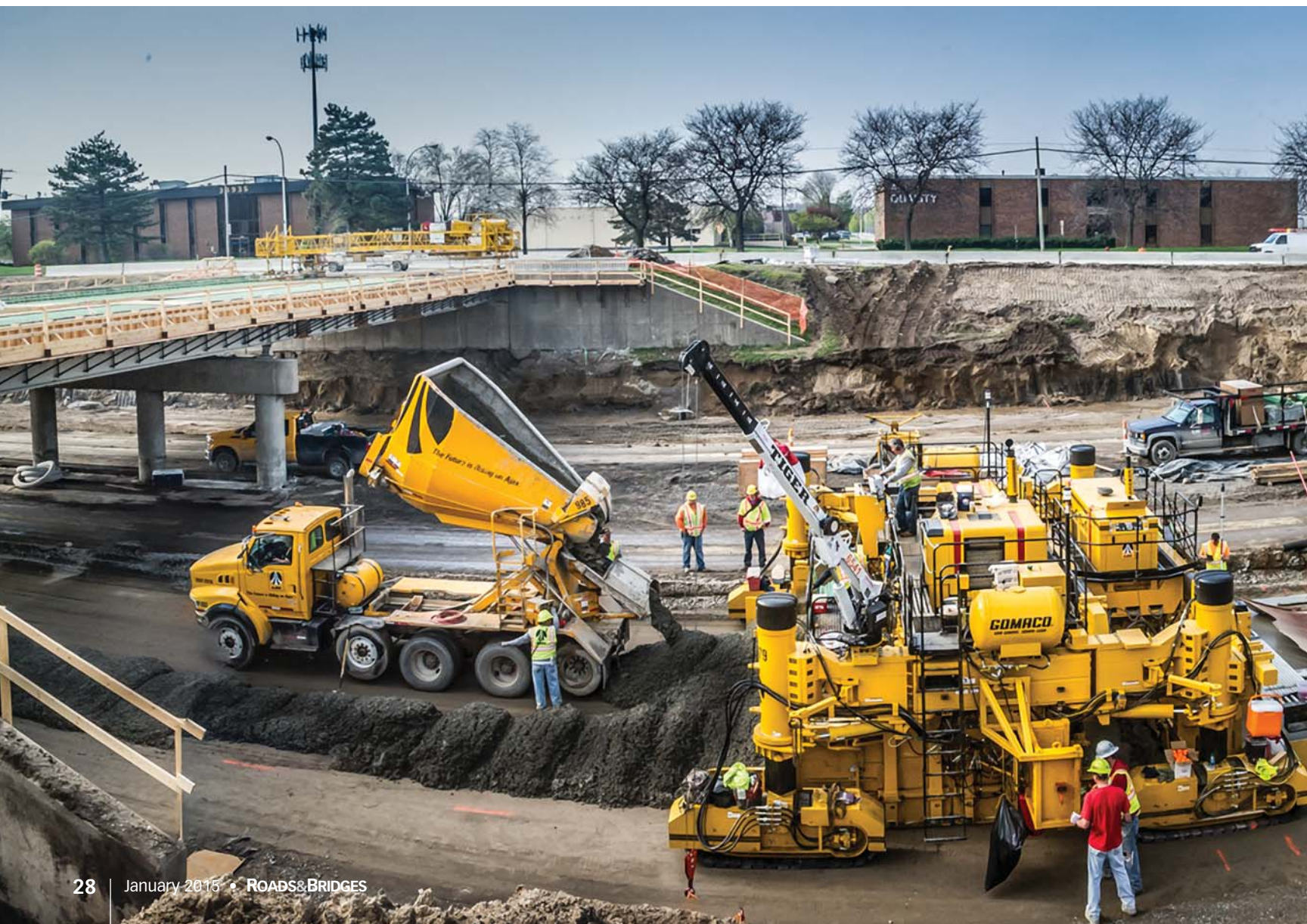
Best when left alone

Full closure and innovation lead to timely completion of a fast-paced megaproject in the Midwest

By Daniel M. DeGraaf, P.E.

How do you deliver 78,298 cu yd of ready mix concrete, 270,000 cu yd of paving concrete, move 1.2 million cu yd of dirt, rehabilitate 30,000 linear ft of sewer line, recycle 700,000 sq yd of concrete pavement, place 850,000 tons of aggregate base and 85,000 linear ft of concrete barrier wall all in less than six months?

Cordoning off an entire freeway is not something entered into lightly. Yet, success on previous roads projects demonstrated to the citizens of Michigan that a full closure of I-96 between I-275 and M-39 would minimize the impact of a reconstruction megaproject aimed at breathing new life into the state's freeway



system. Thus, under full closure, 7 miles of urban freeway including 56 lane-miles of concrete pavement, 22 ramps, 37 bridges, 74 approaches and 10 retaining walls were reconstructed in 167 days. The freeway closure started on April 5, 2014, and it was reopened to traffic in mid-September.

Dan's Excavating, CA Hull and Ajax Paving Industries along with numerous subcontractors and suppliers completed this project encompassing more than 600,000 man-hours with but a single lost-time injury. And aside from plain old hard work, there were several innovations implemented that led to the success of this project, among which electronic contracting, 3-D project control and well-graded concrete mixes stand out.

Going paperless

Electronic or paperless contracting was utilized from design to bidding and throughout project completion. During the design and bidding phase, the engineers, designers and decision makers could all share information and answer questions almost simultaneously, mostly notably concerning the construction drawings, each and every one of which was available at all times to each stakeholder with access via cloud service managed by the Michigan Department of Transportation (MDOT). This same benefit carried on during the construction phase. As questions or conflicts were uncovered, information was easily transferred directly to the decision makers, saving time each day that accumulated to full days saved in process overall. Once a solution was developed, all of the parties in the approval process were instantly brought into the loop. There were admitted struggles with getting all of the project records into common formats that worked with all the unique systems being used today, but the contractors and MDOT staff navigated their way through it. One particular challenge concerned certified payrolls, which, due to the use of federal dollars on this project, were required to be submitted on a weekly basis. Each sub-contracted outfit or unit had its own format, it's own way of doing things—all of which had to be acceptable to and readable by a single interface for the purpose of centralizing records. Labor compliance software known as LCPtracker was utilized to solve this issue, which benefited to project in two important ways—payroll records were managed and tracked efficiently for all contributors to the project and also those records were easily organized in correspondence with federal requirements for federally funded programs.

Going 3-D

Total station grade control was utilized to control all operations from grading and

PHOTO BY JAMES D. LEMAY, MICHIGAN DOT

utility installation to stringless paving. Stringless grade control is the next step in the advance of electronic plans, bidding and project management.

Under standard construction practice, a profile grade line is calculated to the nearest two decimal points for points located at 25- to 50-ft intervals. Cross-slope calculations are utilized to establish additional parallel grade lines. Surveyors lay out grades on lath or hubs, and these points are transferred to a string line with measuring tapes and carpenter levels. Typical survey tolerance is ±0.02 ft for line and grade. After the string line has been initially set it is eyeballed for irregularities and adjusted manually by the contractor crews. This same process may be repeated several times on a project as each layer of the pavement is constructed. In most cases, transition grades from the new pavement to an existing structure are warped into a best-fit condition in the field.

With stringless control, this entire process of establishing the profile lines and grade fine-tuning is totally completed in a 3-D model prior to the start of construction. Profile adjustments are now back in the hands of the design engineer, rather than being delegated to the crew setting the string line. Once established, a surface profile can be used to control the grade of any number of lower layers.

On a typical day, the excavation crew may start cutting final dirt grade, followed closely by the underdrain crew. By mid-morning the aggregate base is being placed, and at noon the final trimming operation sets in to make grade for the next day's concrete pavement construction. With all the players dialed into the same design file and same control points with just a different cut to their grade, inspection staff could spot check any point on any lift with their own total station setup.

Potential utility conflicts were identified and explored during early phases of the work. The engineering staff would set up their instruments and verify any point location on the project site. This information can instantly be sent to the design staff for evaluation.

Adaptation of any new technologic model is not without its challenges—and its lessons learned. 3-D models require key control points and curve equations. The design curve grade transitions need to be calculated to the greatest possible degree of accuracy. Figures to the nearest 0.0001 or greater are crucial to establishing the design profile grades. However, the designer did not have to spend time and effort calculating intermediate station grades. It was critical for the designer to check the transitions between vertical curves and existing structures. The proposed grade profile was run through the Federal Highway Authority's ProVal software, which translated that raw data into an estimated international roughness index (IRI) for each segment of pavement, approximately $^{1}/_{10}$th mile. It was recommended that a design grade IRI target of 10 in. per mile be established for each lane of pavement. This analysis becomes even more necessary with the addition of more driving lanes. IRI is sensitive to grade breaks and slope breaks; therefore, checking outside profile lines where the greatest slope transitions take place was a critical step. Project control points, spaced at 250-ft intervals, were established with an accuracy of at least ±0.001 ft. As the contractor moves through the project, small differences between control points can easily be compounded, which leads to conflicts when tying into an existing fixed point. When a total station instrument is set up for machine control, a minimum of three control points should be cross-checked. Each layer of the pavement structure can be constructed to its own required level of tolerance.

Designing an innovative mix

Well-graded concrete mixes were used to enhance the constructability and durability of the pavements and bridges all along the project site. The paving contractors had been using well-graded mixes for several years, and applied the same method to this project as a proven means. Such mixes do require a significant effort in material handling and pre-production testing, but they provide the producer with a greater level of control of the final product. These mixes are easier to place and finish, and a big additional benefit is that they tend to develop a more stable air system.

Pumping conventional structural mixes into retaining wall forms is at best difficult. Operational as well as sampling and testing issues were a source of contention in the early phases of the I-96 project. Pump pressures fluctuated, as did air content test results. Stopping and starting the pump would be a production problem further complicated

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The conventional concrete mix specified by MDOT was called a "D" mix. MDOT had successfully constructed a few small bridge deck demonstration projects with well-graded mixes with good success. The well-graded reduced paste mixes resulted in a significant reduction in the number of shrinkage cracks as well as an increase in tested compressive strength. The modified concrete deck mix with supplemental cementitious replacements was called "DM-SM." The I-96 project was considered to be a good candidate for a large-scale trial of the new DM-SM concrete mix. As the deck pours started in June, the new DM-SM mix was applied to the project. By mid-July more than 100 pours had been made with the DM-SM mix, and no single acceptance test ever approached an action limit. The consistency of the pumped concrete was great, the tested air content was routinely within a half-point of the targeted 6.5%. The mix looked "wetter" than it really was, and the DM-SM mix was very controllable and workable. Finishers did not have to work hard to finish the surface. Pump operators reported that the conventional D mixes were difficult to pump and hard on their equipment, whereas the DM-SM mix was an extremely easy mix to pump, in consequence of which the pump endured very little strain or pressure. The producers reported that they were getting an added 1 psi per pound of additional cementitious strength over the conventional D mix.

Many of the bridge approach slabs, which were required to be constructed with the paving mix, also had to be pumped on this project. The paving mix required the inclusion of 1.25-in. aggregate. The well-graded paving mix proved to be a very pumpable stable mix even with the larger aggregate.

Producing a concrete mix that was easy to place, pump and finish was a great asset to the production demands of this project. The question now being asked is, "why didn't we do this years ago?" In addition to workability, other significant benefits to this DM-SM mix were reduced permeability and reduced shrinkage cracking potential, both at a potentially lower material cost point. R&B

DeGraaf is executive director of the Michigan Concrete Association.

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