Evaluate Alternatives to Right of Way Drainage Control along the Interstate

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16. Abstract
Ohio Department of Transportation (ODOT) forces undertake routine and sometimes extensive maintenance of roadside ditches that impact the performance and safety of roadway drainage. Unfortunately, county crews have limited options to solve maintenance problems related to paved gutter deterioration and ditch erosion. This research project evaluates the potential viability of alternative processes and products to provide cost effective solutions to maintenance problems.

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1.0 EXECUTIVE SUMMARY

ODOT county maintenance crews are responsible for repairs and modifications to the roadway drainage system, including ditches and paved gutters. In many cases, concrete gutters were installed parallel to the shoulders or offset from the paved surface when the interstate highway system was constructed over 50 years ago. Concrete is subject to deterioration, and thus repair or replacement is necessary when it reaches the end of its design life. Unfortunately, working with cast-in-place concrete for this type of application can be a labor-intensive effort. ODOT Ashland County Maintenance (Ashland County) was seeking to leverage in-house concrete expertise by evaluating the current concrete gutter construction process and possible product and process alternatives. In addition to repairing or replacing existing deteriorated paved gutter, potential research applications would include modifications to existing roadside ditches with erosion problems along two lane routes.

The research approach included surveying a range of public agency employees, including highway, road and bridge maintenance mangers and superintendents, highway and state maintenance engineers, project managers, bridge inspectors and stormwater compliance managers, along with private contractors. Five ditch lining materials were initially considered: cast-in-place concrete, asphalt, tied concrete block mat (Flexamat), articulating concrete block, and Concrete Cloth. Ashland County stated their material preference was cast-in-place concrete with additional consideration for asphalt applications. A preliminary evaluation was performed for asphalt, but ultimately no material alternatives were advanced to field trial as a part of this research.

Evaluation of the current process included construction observations of cast-in-place concrete work performed by Ashland County to replace an existing paved gutter along a multilane divided highway. Evaluation of potential alternatives included primarily equipment alternatives: the possible use of a hoe-ram in lieu of other means to demolish concrete, and the possible use of a slipform machine in lieu of other means to place concrete.

The research findings revealed that Ashland County was already exercising labor efficiencies based on their experienced staff. Specific actions currently utilized to maximize efficiency include creating concrete forms by working in alternating ditch segments as well as selective use of reinforcing steel. Projected cost analysis showed a modest cost savings could be gained by using a skid steer loader with a hoe ram attachment in lieu of a jackhammer or other means of demolishing concrete. While using a slipform machine could save labor for an experienced crew, a life cycle cost analysis showed that it would not make sense for ODOT to pursue the purchase of a slipform machine due to the relative infrequency of use. The learning curve required for a crew to gain familiarity with slipform machines and maintain those skills with frequent use is best undertaken by roadway contractors.

From a policy level regarding roadway drainage system design, the research revealed disconnections between the stated objectives of Ashland County maintenance staff and official policy guidelines developed by ODOT's Office of Hydraulic Engineering. These disconnections are focused on roadway hydraulic concerns regarding the suitability of concrete ditch lining material and ditch capacity as well as environmental hydraulic considerations associated with new impervious area. Recommendations include internal ODOT coordination prior to implementation of any new ditch lining projects, with the exception of repairing or replacing existing paved gutters.

2.0 PROJECT BACKGROUND

For many decades, gutters have served as a significant component of the highway drainage system. Paved gutters are routinely utilized to convey stormwater runoff away from travel lanes and toward receiving sewers and streams. Gutters are often constructed parallel to the roadway either adjacent to shoulders or offset from the paved surface. The Ohio Department of Transportation (ODOT) has established Standard Construction Drawing DM-2.1 (Paved Gutters) for use by roadway designers and contractors. Paved gutters can be effective in their role for stormwater conveyance, but they require periodic maintenance. Common maintenance requirements for paved gutters include the following items:

- Deterioration: Many of the paved gutters installed along I-71 are 50 years old. Over time, rigid gutter materials may deteriorate for numerous reasons, from problems associated with mix design and installation, to environmental exposure. Upon deterioration, the gutter system requires either repair or replacement.
- Settlement: Individual sections of the gutter may settle at different rates due to variations in subsoil materials and compaction during installation. Gutter sections may also displace with subsoils during frost heave conditions. Settlement will create discontinuities in the gutter flow line, resulting in stormwater and sediment accumulation in the gutter. In turn, this accumulation will adversely affect the ability of the gutter to convey stormwater. Gutter sections with settlement failures require replacement.
- Infiltration: Paved gutters prevent stormwater infiltration into the subsoils. When gutters are constructed along the roadway, stormwater infiltration through gutter failures may reach and weaken the pavement base course, resulting in failure of the roadway surface along the shoulder. Upon freezing, water intrusion may also lead to freeze-thaw cracking of the rigid gutter materials. When identified early, repair of failed gutter sections may prevent damage to the roadway. However, if the condition persists, repair to the roadway may be necessary in addition to the gutter system.
- Sediment Accumulation: Sediment from vehicular traffic will naturally buildup along the roadway shoulder. During significant rainfall events, the accumulated sediment will wash off into the gutter and receiving drainage system. Sediment can also be generated through erosion of the earthen slope adjacent to the paved gutter. In areas where the gutter slope is minimal due to design grade, or where gutter settlement has occurred, sediment materials may accumulate in the gutter and reduce the ability of the gutter to convey stormwater runoff. Sediment accumulation requires periodic removal by maintenance forces unless the underlying cause (erosion, slope, settlement, etc.) is corrected.

In Ohio, the ODOT county garages are responsible for the maintenance and repair of gutters along interstate highway routes and standard roadside ditches along two-lane state routes. Gutter repair in these environments is very challenging, as maintenance forces must perform their work within the highway clear zone in the vicinity of high speed vehicular traffic. Existing ODOT paved gutters are primarily constructed of cast-in-place concrete. Standard contraction joints simplify removal practices with clean work lines, but preparing the subgrade and constructing forms can be labor intensive. In addition, the replacement of this material requires consideration for curing time prior to exposure of the newly placed work to stormwater runoff. An unexpected rainfall event may result in damage to the work, erosion, and possibly hazardous conditions along the roadway.

3.0 RESEARCH CONTEXT

3.1 Research Objectives

The goal of this research effort was to identify opportunities to improve ODOT's current procedures for maintaining gutters along the interstate highway routes. It was anticipated improvement opportunities may include modifications to both labor and materials utilized in the maintenance effort. To be considered a successful improvement, the maintenance procedures were required to be consistent with the following objectives:

- Maintain a safe environment for the motoring public: Safety for vehicular operations is of prime importance for roadway design. All recommendations to improve maintenance procedures must be in concert with this tenant.
- Contain and convey stormwater away from the roadway in a controlled manner: The primary purpose of a gutter system is to efficiently collect and convey runoff. Improvement recommendations shall not result in decreased capabilities for stormwater conveyance.
- Maintain or increase pavement life: As previously discussed, stormwater infiltration through failed gutter sections can infiltrate and weaken the pavement base course. Improvement recommendations shall address infiltration and avoid adverse impacts to the pavement life span.
- Maintain or reduce labor, time, and material costs: The ODOT county garages have finite resources in terms of labor and budget to support roadway maintenance activities. Improvement recommendations shall not require additional resources for implementation.
- Maintain or decrease sediment buildup within drainage structures: Sediment buildup in drainage structures requires additional maintenance effort by ODOT forces. Improvement recommendations shall not generate additional sediment that would require an increase in maintenance effort or risk of flooding.
- Maintain or reduce scour: Paved gutters can be effective in conveying runoff down steep slopes while minimizing scour. Improvement recommendations shall provide similar levels of scour control.

Coordination with Ashland County garage staff refined the research objectives as follows:

- Identify an improved process to construct and maintain paved gutters.
- Extend the application of paved gutters.
- Solutions shall be able to be implemented on interstate highways and two lane roads.
- Implementation shall stay within force account limits.

These objectives were addressed through the following activities: Task 1 – Evaluate the current ODOT process for replacing/repairing concrete gutter systems on the interstate, including site visits and construction observations of a gutter maintenance project; Task 2 – Complete an extensive literature search and survey external agencies to compare and contrast maintenance solutions available today, and provide a recommendation on the viable solutions; Task 3 – Provide an analysis of current processes and new processes available for repairing concrete gutter systems using a benefit cost analysis approach; Task 4 – Provide a report to document work activities and findings; and Task 5 – Meeting with ODOT to review the report and discuss recommendations for Phase 2, if warranted.

3.2 Literature Search

The research team performed an initial literature review during the proposal stage of the project. Additional literature review was performed during the project that focused on guidance published by the Departments of Transportation for the states adjacent to Ohio. The literature search summary is found in Appendix A.

The hydraulic capacity of gutters and other open channel conveyance systems has been previously studied and accepted in practice for decades based on research by Manning and others (McCuen 2002). Current roadway drainage conveyance system design methodology is summarized in the Federal Highway Administration (FHWA) publication HEC-22 "Urban Drainage Design Manual". For roads in Ohio, ODOT has published guidance in Location and Design Manual Volume 2 for gutter capacity calculations with reference to multiple design aids. The Location and Design Manual also provides shear resistance values for gutter and ditch systems lined with concrete, as well as other permanent lining materials, including tied concrete block mats and articulating concrete revetment systems. Location and Design Manual Section 1102.3.2 notes that for ditches and channels "a concrete lining should only be used as a last resort".

In addition to the permanent lining products listed in the Location and Design Manual, there are additional products available in the civil infrastructure marketplace. Milliken (2017) reports that Concrete Cloth has been utilized across the United States for ditch lining and scour protection. The North Carolina Department of Transportation has also utilized Concrete Cloth for slope protection at bridge abutments in lieu of riprap or concrete slope paving.

A review of recent research publications did not identify new findings regarding the maintenance of roadway gutter systems. However, ODOT has an active research project, Effective and Efficient Roadside Ditch Cleaning using BMP's for Erosion and Sediment Control. The project is focused on Putnam and Mahoning Counties in Districts 1 and 4, respectively. In addition to looking at ways to increase efficiency and decrease labor hours, the research is considering environmental issues and includes recommendations related to best management practices (BMP's).

4.0 RESEARCH APPROACH

4.1 Initial Coordination and Site Visits

On August 7, 2017, the research team viewed three project locations where roadside drainage improvements had either been constructed or were proposed.

1. The first project site was located at the intersection of State Routes 511 and 302. At this location, Ashland County staff recently installed a concrete gutter and storm sewer system to replace an existing roadside open ditch. The ditch was a known maintenance issue for the county garage staff, as it would frequently fill with debris and cause runoff to backup onto the roadway. Ashland County forces constructed the improvements over a two week period, during which the adjacent roadway was closed to create a safe work area. A small diameter storm sewer and several catch basins were installed within the existing roadside ditch. The concrete gutter was then constructed using formwork to establish the sides of the gutter and hand troweling to create the flowline and surface. Standard 4,000 psi

concrete with air entrainment was utilized for the gutter. A portion of the asphalt roadway was sawcut, removed, and replaced to facilitate construction of the gutter.

2. The second project site was located on State Route 89, south of US Route 250, and just south of the intersection with County Road 1600. At this site, the existing roadside swale was unpaved and experiencing erosion and scour. This was a potential candidate site for replacement of the unpaved roadside swale with a paved gutter.
3. The third project site was located on US Route 30 near State Route 60, on the northwest infield. At this site, an existing concrete gutter system was present to convey stormwater runoff from pipe outfalls to the receiving waterway. The concrete gutter system was significantly deteriorated due to age. This project was a potential candidate site for replacement of the existing paved gutter system with a new paved gutter.

During the site visits, the research team and Ashland County garage staff discussed alternative materials that could be utilized in a paved gutter system and evaluated under this project. Examples of alternative materials include tied concrete block mats, rolled concrete blankets, etc. The county was familiar with tied concrete block mat used for slope protection, but was less familiar with its channel lining applications. Due to the county garage staff's strong expertise with cast-in-place concrete, Ashland County encouraged the research team to focus our research on the use of cast-in-place concrete in paved gutter systems.

The project abstract described improvement opportunities that may include modifications to both labor and materials utilized in the maintenance effort, and the RFP stated solutions should include the utilization of a combination of products and process improvement. However, Ashland County expressed less interest in alternative products and more interest in alternative processes. In addition, a disconnection was identified regarding Ashland County maintenance activities meeting ODOT hydraulic design criteria outlined in L&D Volume 2 (e.g., ditch capacity, ditch protection, pavement spread, etc.). Notably, L&D Vol. 2 states that a concrete ditch lining should be considered only as a last resort, and to contact OHE before using a concrete lining (Sec. 1102.3.2.F).

4.2 Survey

The research team prepared an electronic survey to solicit feedback on the construction and maintenance of roadside gutter systems. The respondents represented a range of public agency employees, including highway, road and bridge maintenance mangers and superintendents, highway and state maintenance engineers, project managers, bridge inspectors and stormwater compliance managers, along with private contractors. The respondents had experience with installing and maintaining primarily cast-in place concrete, but also asphalt, tied concrete block mat (Flexamat), articulating concrete blocks, and Concrete Cloth. Table 1 on the next page presents a summary of the reported level of difficulty for installing the various types of materials.

Ashland County expressed interest primarily in cast-in-place concrete, with some additional consideration for asphalt applications, so the other three material alternatives were excluded from further evaluation. For cast-in-place concrete, 63% of respondents reported it as easy or moderately easy to install. For asphalt, 64% of respondents reported it as moderately difficult to install. These results suggested that using asphalt as a material alternative would be relatively more difficult than cast-in-place concrete. Full results of the survey questionnaire are included in Appendix B.

TABLE 1
Summary of Reported Ease/Difficulty of Installation for Each Material

	Easy to install	Moderately easy to install	Moderately difficult to Install	Difficult to install	Respondent
Cast-in-place concrete	3 (responses)	7	5	1	Agency / Owner
	1	1	2	0	Contractor
Asphalt	1	3	6	0	Agency / Owner
	0	0	1	0	Contractor
Articulating concrete blocks	0	3	0	0	Agency / Owner
	0	1	0	0	Contractor
Tied concrete block mat (Flexamat)	1	2	1	0	Agency / Owner
	2	0	0	0	Contractor
Concrete Cloth	0	1	0	0	Agency / Owner
	0	0	0	1	Contractor

Note: Values represent number of responses received for each difficulty rating.

4.3 Evaluate Current Process

The research team observed construction of a paved gutter application on October 20 and 27, 2017. The project was located at the above mentioned US Route 30 near State Route 60 site. Work performed while the research team was onsite included demolition of the existing concrete gutter and pouring of the new gutter. In general, the work was performed following standard concrete construction techniques. The following detailed observations were made:

- A mid-size backhoe was utilized to demolish the existing concrete gutter. The backhoe was unable to reach the dump truck in a single motion of removal. The rubble needed to be picked up a second time for placement in the dump trucks. Utilization of a larger excavator would allow for additional efficiency and reduction in labor effort for this type of work. ODOT utilizes a small number of larger excavators that were assigned to other projects. A total of four large excavators are shared between eight counties in District 3.
- The crew foreman was very knowledgeable in the proper techniques to perform the work. However, the remainder of the crew was not as experienced. Additional training and experience for the crew would allow for additional efficiency and reduction in labor effort for this type of work. Through additional training and skills development, further delegation of tasks will optimize labor time spent.

- The technique used to pour concrete in this particular setting was suitable. For other settings with less access, however, it might be advisable to use a concrete pump truck.

Following completion of the US Route 30 project, cost data for labor, materials, and equipment were provided by Ashland County for purposes of baseline comparison. The total length of the US Route 30 project was approximately 118.5 feet (36.1 meters), and the finished quantity reported by Ashland County was 225 square feet (20.9 square meters), which included the ditch plus additional area at storm sewer outfalls. The overall project cost was $25,644, and the calculated unit cost was $31.08 per square foot ($279.72 per square yard) or $216.41 per linear foot. The research team also reviewed historical bid item data from 2014 to 2017 in order to benchmark the cost data for comparable work performed by ODOT roadway contractors. For projects with similar quantities, the award prices for Gutter Removed ranged from $5.00 to $46.00 per square yard, and award prices for Paved Gutter, Type 1-4, ranged from $71.50 to $155.45 per linear foot.

Figure 1. Observation of Current Ashland County Process. Left: Deteriorated concrete demolition. Right: New concrete placed in alternating segments.

4.4 Evaluate Alternatives

4.4.1 Materials

Although external survey responses supported the idea of potential alternatives for paved gutters and ditch lining materials, Ashland County's interest with this research was limited to cast-in-place concrete. Ashland County staff expressed some initial interest in asphalt as a material alternative, but the survey results suggested asphalt would generally be more difficult to work with than cast-in place concrete. With regard to roughness, both asphalt and concrete are relatively smooth, which leads to comparable flow velocities and scour potential. However, asphalt performance is affected by spreading and compaction specifications, and it is anticipated that specialized equipment or hand methods would be required. Overall, it was concluded that asphalt paved ditches would not meet the stated objectives of the research project. As such, no material alternatives to cast-in-place concrete were advanced to field trial.

4.4.2 Equipment

Ashland County garage staff asked the research team to evaluate savings associated with the use of a skid steer loader with a hoe-ram attachment. The intent would be to use this set-up for concrete demolition work, replacing manual efforts with a jackhammer as well as the technique of using an excavator bucket to break up the concrete prior to removing the old material. However,

it would still be necessary to use the excavator bucket to move rubble to the dump truck. The expected cost savings are summarized below in Table 2.

TABLE 2
Summary of Estimated Cost Savings

Scenario	Labor	Equipment	Materials	Total	Savings
ASD-30 Cost Data	$13,674	$5,987	$5,983	$25,644	
Alternative 1: Skid Steer Loader	$13,674	$5,295	$5,983	$24,952	2.7%
Alternative 2: Slipform Machine	$10,256	$8,548	$4,822	$23,626	7.9%
Alternative 3: Combination	$10,256	$7,856	$4,822	$22,934	10.6%

The research team suggested consideration of a slipform machine in order to improve the efficiency of the concrete casting operation and reduce the labor aspect of the job. The suggested scenario included the use of a concrete pump attachment for the skid steer loader to feed the slipform machine. It is expected that a slipform machine could be used for projects similar to either US Route 30 (offset from roadway) or State Route 511 (adjacent to roadway) with the proper molds. However, in both configurations, it would be necessary to properly prepare the subgrade in advance. As an example of a suitable slipform machine, Power Curbers Inc. supplies a curb machine (PWC5700-C) that can be used to slipform a variety of ditch configurations in addition to standard curb and gutter (see Figure 2 below). The research team contacted the company in order to evaluate the expected equipment costs, life cycle analysis, and any potential labor savings. The company expressed concern that specialized training is required to operate the slipform machine, and personnel that infrequently operate the equipment would require additional time and labor expense to construct a project. Ashland County expects they would perform approximately one project per year similar to the US Route 30 project observed during this research (approximately 120 linear feet of gutter construction). For equipment purchase, however, the break-even point would require ODOT county forces to construct approximately 150 similar projects over the life span of the machine. Cost analysis calculations and summary data shown in Table 2 assume acquisition and use of the slipform machine would be evenly shared among all eight counties within District 3, and each county would construct at least one similar size project per year. The detailed cost analysis is included in Appendix F.

Figure 2. Curb Machine PWC5700-C V-Ditch Applications (Source: PowerCurbers Inc.)

4.4.3 Process

The current process evaluation demonstrated that the current Ashland County crew foreman for this type of work already has the necessary level of technical expertise needed to make cost-effective decisions, such as staggering the work by removing every other segment of ditch to reduce the need for grade-checking, and applying reinforcing steel only as needed. The crew had less expertise, though, and it is expected that a certain level of overall inefficiency is due simply to lack of experience and general organization of efforts. Supplementing the use of an excavator with a skid steer loader as described above is not expected to reduce overall labor costs. For potential slipform applications where existing paved gutters are replaced similar to US Route 30, a key difference compared to the field observations would be the level of effort required on the front end to prepare the subgrade and perform grade checking. It is anticipated that all of the existing deteriorated gutter would be removed up front, eliminating the efficiency of using every other existing segment to establish proposed grades.

5.0 RESEARCH FINDINGS AND CONCLUSIONS

Cast-in-place concrete is frequently the material of choice for paved gutters, and it is clearly the preference for the Ashland County garage staff. The survey found that using asphalt as a material alternative may be relatively more difficult than cast-in-place concrete. Asphalt performance is affected by spreading and compaction specifications, and it is anticipated that specialized equipment or hand methods would be required. Asphalt is equivalent to concrete with regard to flow velocities and scour potential. Overall, it was concluded that an asphalt material alternative for ditch lining is not consistent with the goals of the research project. Further evaluation of articulating concrete blocks and tied concrete block mat could be warranted in a different ODOT county with less cast-in-place concrete expertise or more desire to test alternative materials for roadway ditch installations.

Each project site is expected to be unique with regard to optimal equipment needs. A cost-effective project begins with the evaluation of equipment availability, site access, and project priority in addition to labor. It is necessary to consider the distance between edge of pavement and ditch as well as embankment cross slopes for site access concerns and then determine what types of equipment would be best suited to the site. It is best to arrange the work/labor schedule to coincide with optimal equipment availability. A heavy excavator is appropriate where the distance between roadway and ditch are comparable to the US Route 30 project, approximately 30 to 60 feet (9 to 18 meters). On the other hand, a mid-size excavator may be perfectly adequate and more cost-effective for locations like State Route 511 with the ditch immediately adjacent to the pavement. For situations with difficult site access, a concrete pump truck would be preferable to back-and-forth trips by an excavator bucket used to transport concrete. ODOT is expected to see an equipment cost savings with the use of a skid steer loader and hoe-ram attachment compared to a jackhammer and/or excavator used for concrete demolition. However, it is expected that an excavator would still be required for removal of concrete rubble.

Slipform machine work performed by county garage maintenance crews is estimated to provide 25% labor cost savings, but there would be an estimated 43% increase in equipment costs, and the net total cost savings would be approximately 8%. Equipment costs assume the machine is adequately utilized by all eight counties in District 3 to reduce the cost impact of machine acquisition applied to each project. With an experienced and efficient operating crew, a slipform

machine would reduce the amount of labor required to place concrete. However, it would not decrease the amount of labor-intensive work associated with subgrade preparation. More importantly, the life cycle cost analysis showed that the initial expense of purchasing equipment would far outweigh the estimated labor cost savings given the relative infrequency of this type of work performed by maintenance crews. A majority of slipform machines like the Power Curber PWC5700-C are sold to concrete subcontractors who use them extensively (i.e., 700 to 1000 hours per year, with total output between 1.5 and 4.2 million linear feet). Given the level of concern about labor-intensive work combined with the relative infrequency of this type of work performed by county maintenance crews, it is expected that ODOT could see the most cost-savings by using an experienced contractor to install or replace paved gutters as warranted.

In general, there is a disconnect between policies originating from the Office of Hydraulic Engineering and the maintenance work performed by ODOT county garage staff. Using cast-in-place concrete for replacement of existing paved gutters presents no cause for concern at the agency level. However, new installations of concrete ditch linings give rise to issues beyond typical county garage responsibilities. For example, roadway designers are required to analyze ditch capacity and allowable shear stress, and ODOT L&D Volume 2 states: “A concrete lining should only be considered as a last resort. Contact OHE, before using a concrete lining.” From an environmental hydraulic standpoint, it is widely accepted that increased impervious area (e.g., pavement, concrete lined waterways, etc.) causes overall negative watershed effects, and the current trend is in the direction of utilizing non-structural solutions, as appropriate.

6.0 RECOMMENDATIONS FOR IMPLEMENTATION OF RESEARCH FINDINGS

Recommendations based on research findings primarily focus on alternative equipment use and improved internal ODOT coordination. With regard to product alternatives, it is not recommended that Ashland County pursue the use of asphalt for roadway ditch lining.

Process recommendations are site specific, beginning with evaluation of equipment availability, site access, and project priority. It is necessary to consider the distance between edge of pavement and ditch in addition to cross slopes and determine what types of equipment would be best suited to the site. To the extent possible, arrange the labor schedule to coincide with equipment availability. Use a mid-size excavator where the ditch is immediately adjacent to the pavement, and use a large excavator with a longer reach where the distance between roadway and ditch is approximately 30 to 60 feet (9 to 18 meters) or greater.

It is generally recommended that Ashland County avoid the use of a jackhammer for concrete demolition of deteriorated paved gutters. Instead, county garage staff should use of a skid steer loader with hoe-ram attachment working in tandem with an excavator for removal. For Ashland County, there is no additional cost, because they already have access to this equipment. The expected project cost savings is $0.84 per square foot, or $5.84 per linear foot (approximately 3% compared to the current process).

Where Ashland County garage staff choose to replace deteriorated concrete ditch linings in-kind, it is recommended that work occur in alternating stages with sections approximately 10 feet (3 meters) in length, similar to the U.S. Route 30 project observed during this research. Remove every other section and use remaining sections to help guide the installation of concrete forms in

between and reduce the need for grade-checking. In order to improve labor efficiency additional in-house staff training is recommended for this type of cast-in-place concrete work.

It is not recommended that Ashland County garage staff purchase a concrete slip form machine such as the Power Curber, because the initial purchase cost ($250,000 to $300,000) is prohibitive, and the break-even point for cost savings far exceeds the projected usage.

For maximum efficiency and cost-savings to ODOT, it is recommended that county garage staff coordinate with District planning and production personnel to incorporate paved gutter installation or replacement as part of routine pavement maintenance projects or as a District-wide gutter maintenance project. In this scenario, it is anticipated a pavement contractor could hire a subcontractor to perform the concrete ditch work as needed.

In general, more consideration should be given to ODOT hydraulic design criteria specific to ditch capacity and ditch protection as outlined in L&D Volume 2. Prior to publication of the research results, it is recommended that the Office of Hydraulic Engineering coordinate directly with the Office of Maintenance to discuss any concerns related to hydraulic performance of concrete linings as well as the new impervious area and water quality impacts resulting from paved gutter projects performed by county maintenance crews. It is further recommended that research results be coordinated with the parallel ODOT project, Effective and Efficient Roadside Ditch Cleaning using BMP's for Erosion and Sediment Control. At the county and district level, it is recommended that Transportation Administrators coordinate with in-house design staff prior to initiating any modifications to the roadway drainage system, including construction of new paved gutters.

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APPENDIX A:

Literature Review

The research team performed an initial Literature Review during the proposal stage of the project. Additional Literature Review was performed during the project that focused on guidance published by the Departments of Transportation for the states adjacent to Ohio.

- Current roadway drainage conveyance system design methodology is summarized in the Federal Highway Administration (FHWA) publication HEC-22 "Urban Drainage Design Manual". Section 4.3 provides detailed hydraulic design guidance for gutter systems with shallow swales similar to the applications covered under this research project. Additional guidance is provided in Section 5 for the hydraulic design of roadside and median channels. Channel lining materials are discussed, including flexible materials (riprap and permanent turf reinforcement mats) and rigid materials (concrete and prefabricated paving blocks). Paragraph 5.1 notes "In general, when a lining is needed, the lowest cost lining that affords satisfactory protection should be used."

- For roads in Ohio, ODOT has published guidance in Location and Design Manual Chapter 11 for gutter capacity calculations with reference to multiple design aids. The Location and Design Manual also provides shear resistance values for gutter and ditch systems lined with concrete, as well as other permanent lining materials, including Tied Concrete Block Mats (Figure 1) and an Articulating Concrete Revetment System (Figure 2). Tied Concrete Block Mats, also known by the product name Flex-A-Mat, consist of precast concrete blocks connected by a high strength geogrid. The product has been utilized extensively in Ohio for scour resistance at pipe outlets, as permanent ditch lining for shear resistance, and for lining gutters discharging down embankments and oriented perpendicular to the roadway. An advantage of Tied Concrete Block Mats is the product can be installed rapidly using basic construction equipment. Articulating Concrete Revetment Systems function similar to Tied Concrete Block Mats, but include larger concrete blocks and higher strength cables for greater shear resistance. Accordingly, larger construction equipment is required for installation of the Articulating Concrete Revetment Systems due to the increased weight of the material. ArmorFlex is an example product currently approved by ODOT for use as Articulating Concrete Revetment Systems. Both Tied Concrete Block Mats and Articulating Concrete Revetment Systems provide an advantage over a rigid paved gutter in that they are flexible and not prone to damage as the result of soil settlement or heaving; however, they are also inherently permeable and allow for stormwater infiltration. Location and Design Manual Section 1102.3.2 notes that for ditches and channels "a concrete lining should only be used as a last resort".

- In addition to the permanent lining products listed in the Location and Design Manual, there are additional products available in the civil infrastructure marketplace. Milliken has produced a rolled liner consisting of fiber reinforced cement that hardens upon hydration. The product, Concrete Cloth (Figure 3), is readily transportable in rolls and can be cut and molded to fit specific site conditions. The Concrete Cloth product has been marketed globally for a variety of uses, also under the name Concrete Canvas. Milliken reports that Concrete Cloth has been utilized across the United States for ditch lining and scour protection. The North Carolina Department of Transportation has also utilized Concrete Cloth for slope protection at bridge abutments in lieu of riprap or concrete slope paving.

- The Indiana Design Manual has published guidance for the selection of roadside channel lining material based on tractive force. Section 203 of the manual states lining material selection should reflect both initial costs and long term maintenance cost. Paved channels should be used when tractive force exceeds 3%. Additional information regarding paved channels is provided in Section 607, which requires Concrete Class A (28 day compressive strength = 3,500 psi) and #4 deformed reinforcing bars per Standard Drawing E 607-PSDT-01 through -06 (Figure 4).

- The Kentucky Transportation Cabinet (KYTC) has published guidance for selection of roadside channel lining material. Narrative discussion is provided for flexible linings (grass, turf reinforcing mats, aggregate lining, and gabion mattress units) and rigid linings (concrete paving, grouted riprap, and modular block). For concrete paving lining, the Drainage Manual states "Due to the high failure rate of paved lining channels, paved lining will be used only in extreme cases with the approval of the Division of Highways." The manual further states that it can be advantageous to pave ditches on very flat slopes to lessen sedimentation and reduce flow depth. Scour protection is required at the downstream terminus of the paved ditch. Similar to the Indiana Design Manual, the KYTC guidance specifies Concrete Class A (28 day compressive strength = 3,500 psi) and #4 deformed reinforcing bars for paved concrete linings. Standard Drawings RDD-001-5 & -6 are provided as Figure 5.

- The Pennsylvania Department of Transportation (PennDOT) has published channel linings design guidance in the PennDOT Drainage Manual. Section 8.8 of the manual states that, wherever possible, the channel lining should make use of native, natural materials such as grass, crushed rock and earth: however, it often requires other types of materials for hydraulic, economic, safety, aesthetic and environmental reasons. Flexible linings (riprap, gabions, vegetation, geotextiles, and articulated blocks and mats) and rigid linings (concrete, soil cement, grout bags, and grouted riprap) are discussed in the manual.

  PennDOT has developed a 7-step process to select a type of channel lining for a site. It uses a procedural step by step analysis to determine if a lining is necessary by analyzing various design considerations (i.e. grade, flow capacities, velocities, shear stresses, etc.). Table 8.9 (extracted, shown on the next page) demonstrates the Channel Lining Applications and Considerations when selecting a lining.

Table 8.9 Channel Lining Application and Considerations

Lining Type	Considerations					
	Functional Longevity	Immediate Stabilization	Seasonal	Construction Effort	Initial Cost	SWM Benefits
Grass	Perm	No	Yes	Minimal	Low	Yes
Sod	Perm	Yes	Yes	Intensive	High	Yes
RECP [1]	Temp/Perm	Yes	No	Moderate	Moderate	Yes
Rock (Riprap)	Perm	Yes	No	Moderate	Moderate	No
Concrete	Perm	Yes	Yes	Intensive	High	No

[1] Rolled Erosion Control Products

  For paved concrete linings, PennDOT Standard Drawing RC-40M (Figure 6) requires Concrete Class A (28 day compressive strength = 3,000 psi) and welded wire fabric reinforcement.

- The Michigan Department of Transportation (MDOT) has published guidance for the selection of roadside channel lining material based on ditch grade. Guidance is published in Chapter 4 of the Drainage Manual, which references lining material selection based on below Table 4-5 (extracted). Additional information regarding paved channels is provided, including Concrete 28

day compressive strength = 3,500 psi), #4 epoxy coated deformed reinforcing bars and welded wire fabric per Standard Drawing R-46-D (Figure 7).

Table 4-5 Permanent Stabilization Treatments for Various Ditch Grades

PERMANENT STABILIZATION TREATMENTS FOR VARIOUS DITCH GRADES	
Ditch Bottom Treatment	**Ditch Grades**
Seed and Mulch *	0.3% to 0.5%
Standard Mulch Blanket *	0.5% to 1.5%
High Velocity Mulch Blanket or Sod *	1.5% to 3.0%
Turf Reinforcement Mat or Cobble Ditch	3.0% to 6.0%
Specific Design Required **	6.0% +

* When within 200 feet of a stream, the permanent ditch treatment will be mulch blanket for ditch grades 0.5 percent or less and sod for ditch grades between 0.5 and 3.0 percent. The designer should set up a miscellaneous quantity of mulch blanket (if not already set up) and high velocity mulch blanket to use in case sod is not immediately available or it is outside of seasonal sodding limits.

** Downspouts, see Standard Plan R-32-Series; paved ditches, see Standard Plan R-46-Series; for spillways consult with the Design Engineer - Hydraulics/ Hydrology.

- The West Virginia Division of Highways has published guidance on the selection of channel lining materials in Chapter 7 of the Drainage Manual. Linings are classified as flexible (riprap, gabions, and vegetation) or rigid (concrete, grouted riprap, and stone masonry). The Manual notes that rigid linings are seldom used due to environmental restrictions. Standard Plan DR-8 (Figure 8) provides details for paved concrete ditch lining using concrete with 3,000 psi 28 day compressive strength, #4 deformed bars and welded wire fabric reinforcement.

- A review of recent research publications did not identify new findings regarding the maintenance of roadway gutter systems. Zimmerman (2007) noted the importance of connecting maintenance activities to an effective condition assessment system. Condition assessments and benefit cost analyses can be utilized to justify preventative maintenance of civil infrastructure, with the goal of extending the life span of many infrastructure components and minimizing the need for and impacts of a full scale replacement project. In terms of gutter system maintenance, examples of preventative maintenance include the application of sealers to reduce water intrusion through concrete surfaces, correction of minor settlement deficiencies, periodic sediment removal, and many others. As earlier noted, sediment removal should be considered as a long-term maintenance responsibility (McGee 2009). Sediment will continue to be generated by vehicular traffic, to be mobilized by runoff during rainfall events, and to accumulate at locations in the stormwater conveyance system where adequate energy is no longer present to continue transporting the sediment material. Planned locations for sediment collection and removal can be identified to focus maintenance activities.

- ODOT has an active research project, Effective and Efficient Roadside Ditch Cleaning using BMP's for Erosion and Sediment Control (SJN 135204). In addition to looking at ways to increase efficiency and decrease labor hours, the research is considering environmental issues and includes recommendations related to best management practices (BMP's).

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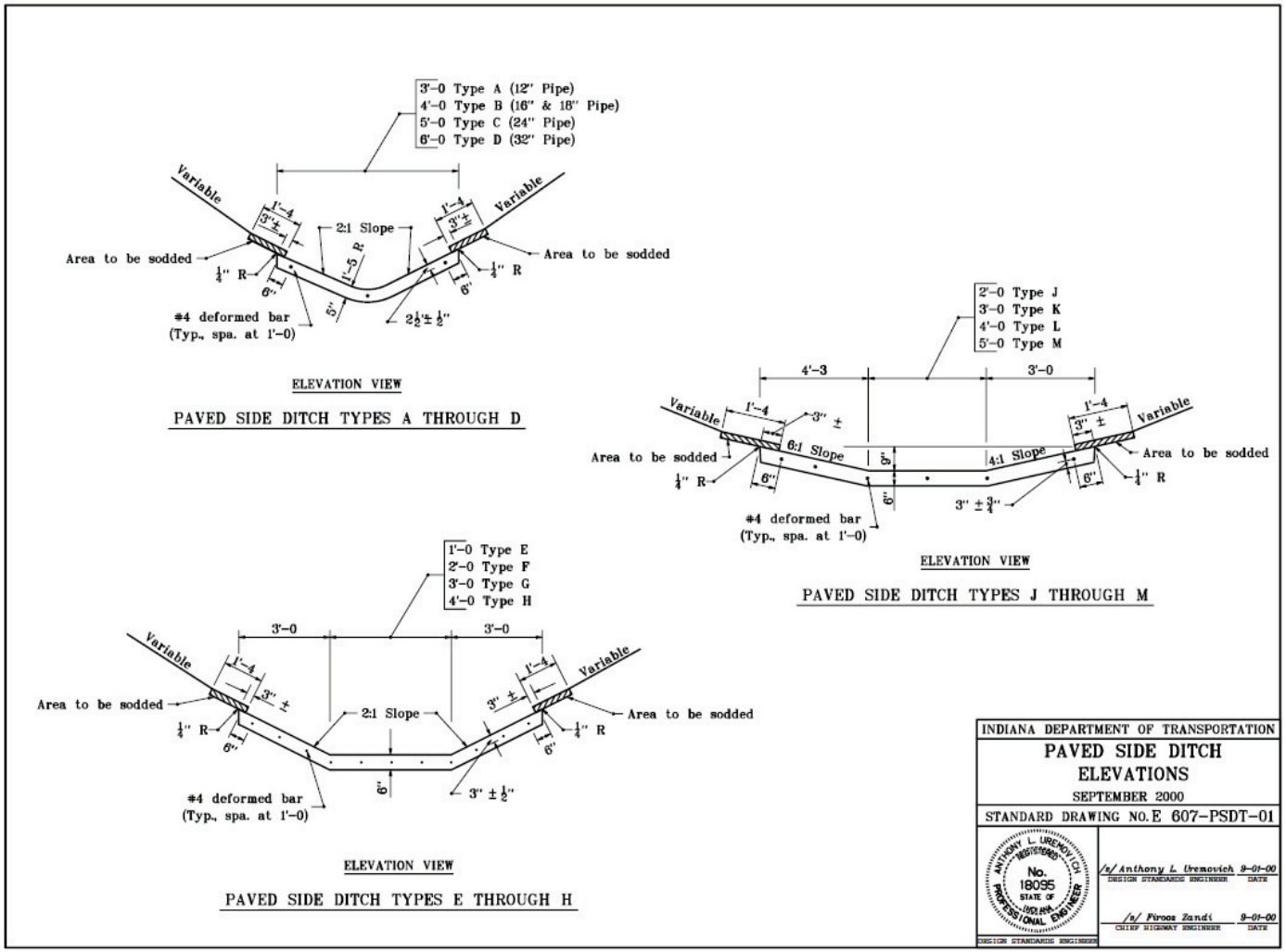
Zimmerman, K.A., and Stivers, M. (2007). A Model Guide for Condition Assessment Systems, NCHRP Project 20-07, Task 206. National Cooperative Highway Research Program, Washington, D.C.

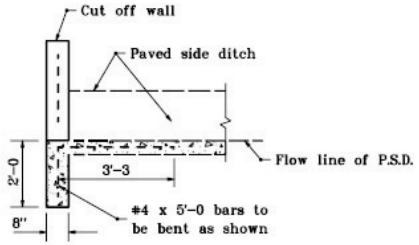
Figure 1: Tied Concrete Block Mat
http://www.flexamat.com/applications/roadways-dot-erosion-protection

Figure 2: Articulating Concrete Revetment
http://www.conteches.com/products/erosion-control/hard-armor/armorflex#1879212-photos

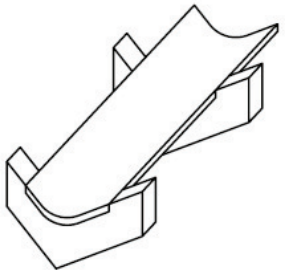
Figure 3: Concrete Cloth
http://infrastructure.milliken.com/pages/products/detail/2/72/

Figure 4 (1 through 6): Indiana Design Manual Standard Drawings:



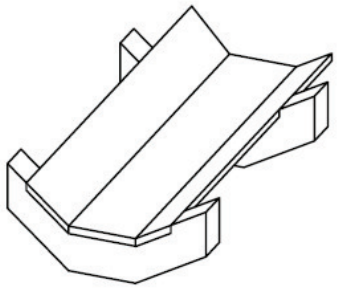


SECTION A–A



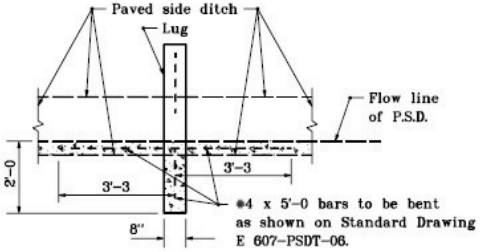
ISOMETRIC VIEW

PAVED SIDE DITCH TYPE A THROUGH D

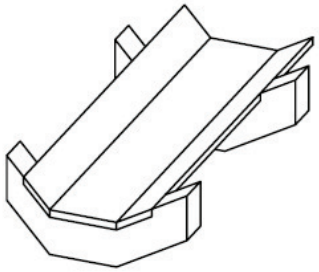


ISOMETRIC VIEW

PAVED SIDE DITCH TYPES J THROUGH M



SECTION B–B



ISOMETRIC VIEW

PAVED SIDE DITCH TYPE E THROUGH H

INDIANA DEPARTMENT OF TRANSPORTATION

PAVED SIDE DITCH
SECTIONS AND ISOMETRICS

SEPTEMBER 1997

STANDARD DRAWING NO. E 607-PSDT-02

ANTHONY L. URENOVICH REGISTERED No. 18095 STATE OF INDIANA PROFESSIONAL ENGINEER

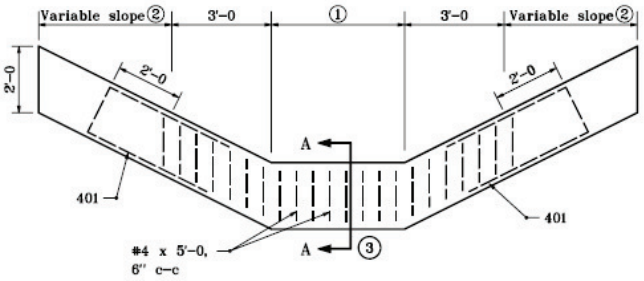
DESIGN STANDARDS ENGINEER

DETAILS PLACED IN THIS FORMAT 11-15-99

/s/ Anthony L. Urenovich 11-15-99
DESIGN STANDARDS ENGINEER DATE

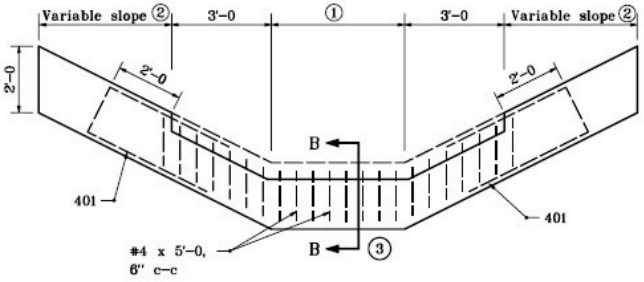
/s/ Firooz Zandi 11-15-99
CHIEF HIGHWAY ENGINEER DATE

ORIGINALLY APPROVED 9-01-97



ELEVATION VIEW

CUT-OFF WALL FOR PAVED SIDE DITCH TYPES E THROUGH H



ELEVATION VIEW

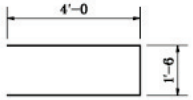
LUG FOR PAVED SIDE DITCH TYPES E THROUGH H

GENERAL NOTES

① 1'-0 For Type E
2'-0 For Type F
3'-0 For Type G
4'-0 For Type H

② 3'-0 For Type E & F
4'-0 For Type G & H

③ See Standard Drawing E 607-PSDT-02 for Sections A-A and B-B.



401 x 9'-6

INDIANA DEPARTMENT OF TRANSPORTATION

PAVED SIDE DITCH
CUT-OFF WALL AND LUG

SEPTEMBER 1997

STANDARD DRAWING NO. E 607-PSDT-03

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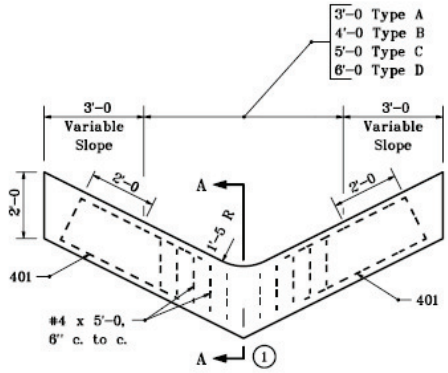
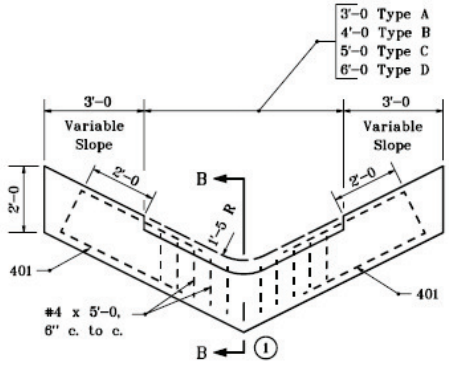
CHIEF HIGHWAY ENGINEER DATE

ORIGINALLY APPROVED 9-01-97



ELEVATION VIEW

CUT-OFF WALL FOR PAVED SIDE DITCH TYPES A THROUGH D



ELEVATION VIEW

LUG FOR PAVED SIDE DITCH TYPES A THROUGH D

GENERAL NOTES

(1) See Standard Drawing E 607-PSDT-02 for Sections A-A and B-B.

2. See Standard Drawing E 607-PSDT-03 for 401 bending diagram.

INDIANA DEPARTMENT OF TRANSPORTATION

PAVED SIDE DITCH
CUT-OFF WALL AND LUG
SEPTEMBER 1997

STANDARD DRAWING NO. E 607-PSDT-04

DETAILS PLACED IN THIS FORMAT 11-15-99

ANTHONY L. UREMOVICH REGISTERED No. 18095 STATE OF INDIANA PROFESSIONAL ENGINEER

/s/ Anthony L. Uremovich 11-15-99
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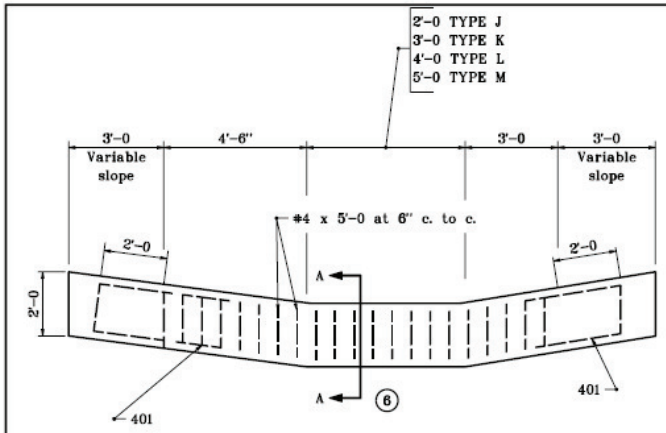
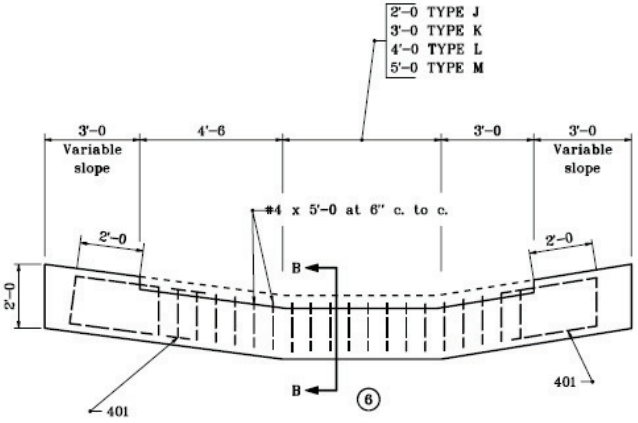
/s/ Firooz Zandi 11-15-99
CHIEF HIGHWAY ENGINEER DATE

DESIGN STANDARDS ENGINEER

ORIGINALLY APPROVED 9-01-97



ELEVATION VIEW
CUT-OFF WALL FOR PAVED SIDE DITCH TYPES J THROUGH M



ELEVATION VIEW
LUG FOR PAVED SIDE DITCH TYPES J THROUGH M

GENERAL NOTES

1. The 6:1 sloped side shall be placed nearest the roadway.
2. Cutt-off walls shall be used at the begining and end of all paved side ditch.
3. Lugs shall be used at the following locations:
   a. 10 ft downslope from a grade change.
   b. 10 ft downslope from the intersection of different types of paved side ditch.
   c. At the downslope end of a transition between different types of paved side ditch.
   d. At the intervals as follows:

Interval	Grade
200 ft	3% to 5%
150 ft	5% to 8%
100 ft	8% to 10%
50 ft	10% & above

4. Paved side ditch transitions shall be required at intersections with earth ditches and pipe culverts. These transitions shall be converted to equivalent lengths of the type of paved side ditch specified at these locations.
5. Transitions of 10 ft or less shall be required between two different types of paved side ditch. Such transitions shall be converted to equivalent lengths of the larger type of paved side ditch specified at these locations.

(6) See Standard Drawing E 607-PSDT-04 for Sections A-A and B-B.

7. See Standard Drawing E 607-PSDT-03 for 401 bending diagram.

INDIANA DEPARTMENT OF TRANSPORTATION

P.S.D. CUT-OFF WALL & LUG AND GENERAL NOTES

JANUARY 2000

STANDARD DRAWING NO.E 607-PSDT-05

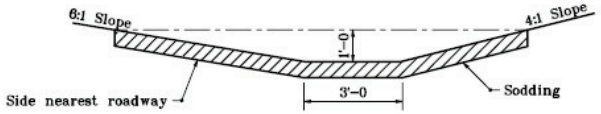
ANTHONY L. UREMOVICH REGISTERED No. 18095 STATE OF INDIANA PROFESSIONAL ENGINEER
DESIGN STANDARDS ENGINEER

/s/ Anthony L. Uremovich 1-03-00
DESIGN STANDARDS ENGINEER DATE

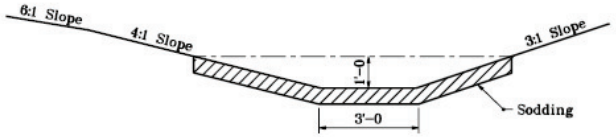
/s/ Firooz Zandi 1-03-00
CHIEF HIGHWAY ENGINEER DATE

GENERAL NOTES

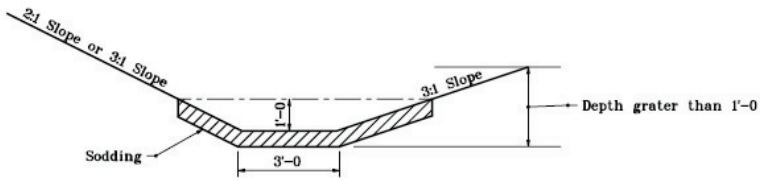
1. See Standard Drawing E 607-PSDT-02 for Section B-B.



STANDARD 3' BOTTOM DITCH
(LOCATED WITHIN CLEAR ZONE)

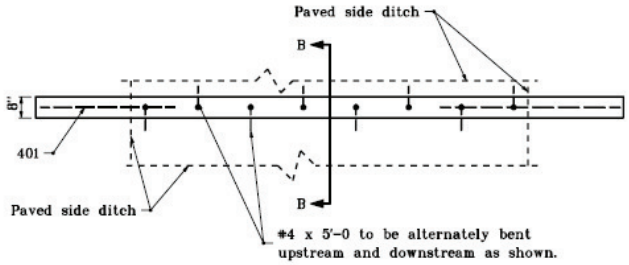


SPECIAL 3' BOTTOM DITCH
(LOCATED BEYOND CLEAR ZONE)



SPECIAL 3' BOTTOM DITCH
(LOCATED BEYOND CLEAR ZONE)

SODDED DITCH DETAILS



PLAN VIEW OF LUG (TYPICAL FOR ALL TYPES)

INDIANA DEPARTMENT OF TRANSPORTATION

P.S.D. LUGS &
SODDED DITCH DETAILS

SEPTEMBER 1997

STANDARD DRAWING NO. E 607-PSDT-06

ANTHONY L. UREMOVICH REGISTERED No. 18095 STATE OF INDIANA PROFESSIONAL ENGINEER
DESIGN STANDARDS ENGINEER

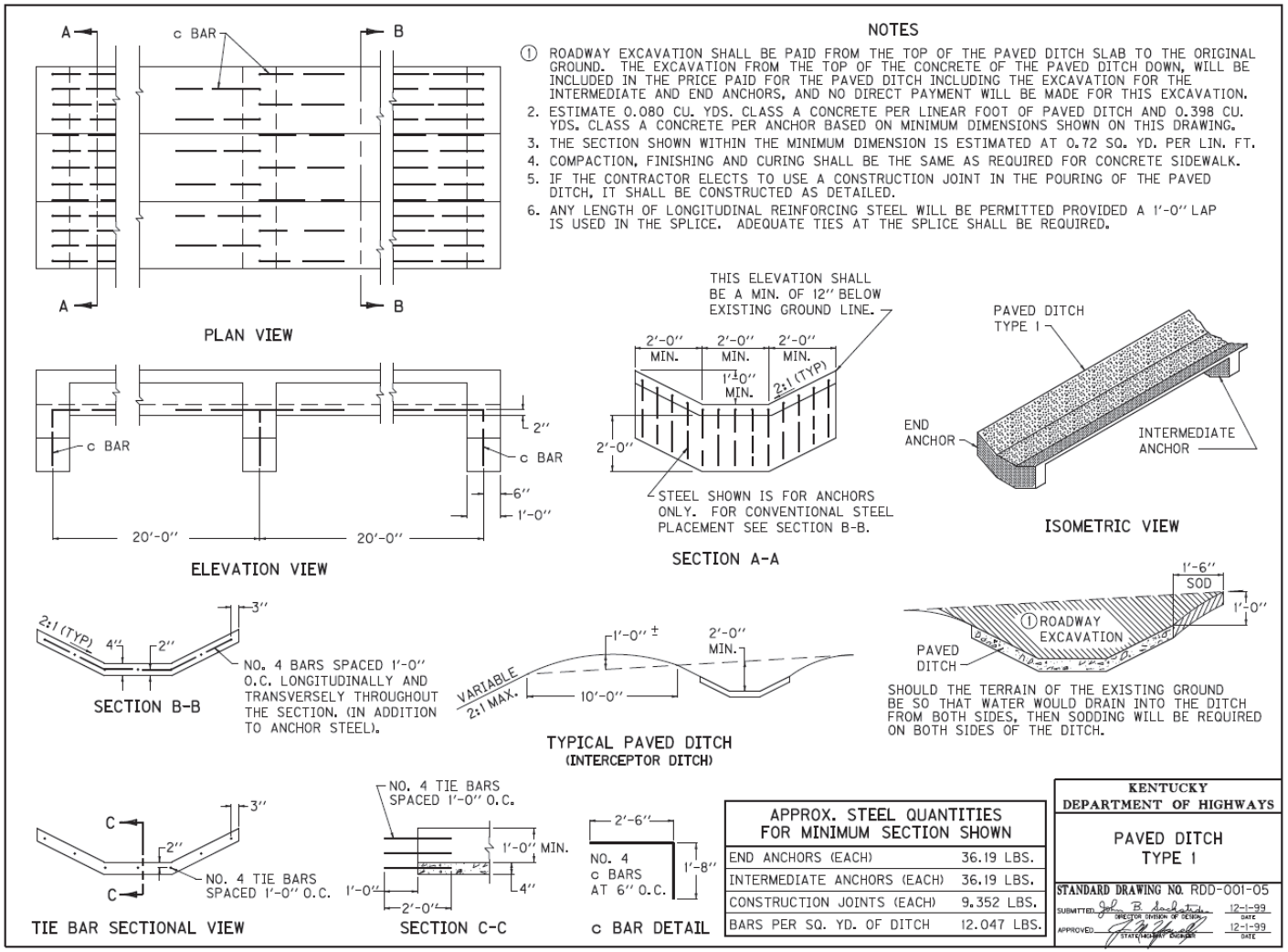
DETAILS PLACED IN THIS FORMAT 7-27-99

/s/ Anthony L. Uremovich 7-27-99
DESIGN STANDARDS ENGINEER DATE

/s/ Firooz Zandi 7-27-99
CHIEF HIGHWAY ENGINEER DATE

ORIGINALLY APPROVED 9-01-97

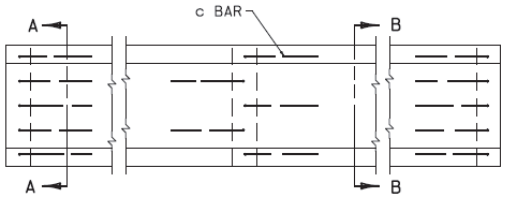
Figure 5 (1 through 2): Kentucky Division of Highways Standard Drawings:



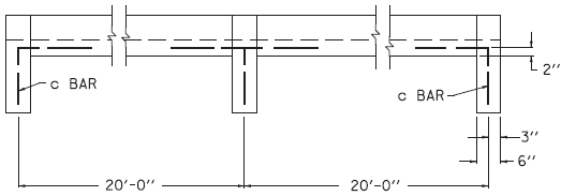
NOTES

① ROADWAY EXCAVATION SHALL BE PAID FROM THE TOP OF THE PAVED DITCH SLAB TO THE ORIGINAL GROUND. THE EXCAVATION FROM THE TOP OF THE CONCRETE OF THE PAVED DITCH DOWN, WILL BE INCLUDED IN THE PRICE PAID FOR THE PAVED DITCH INCLUDING THE EXCAVATION FOR THE INTERMEDIATE AND END ANCHORS, AND NO DIRECT PAYMENT WILL BE MADE FOR THIS EXCAVATION.

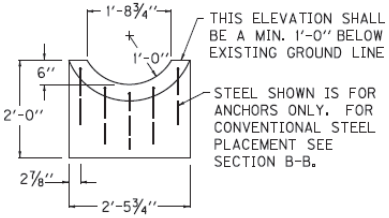
2. ESTIMATE 0.032 CU. YDS. CLASS A CONCRETE PER LINEAR FOOT OF PAVED DITCH AND 0.060 CU. YDS. CLASS A CONCRETE PER ANCHOR BASED ON MINIMUM DIMENSIONS SHOWN ON THIS DRAWING.
3. THE SECTION SHOWN WITHIN THE MINIMUM DIMENSION IS ESTIMATED AT 0.27 SQ. YD. PER LIN. FT.
4. COMPACTION, FINISHING AND CURING SHALL BE THE SAME AS REQUIRED FOR CONCRETE SIDEWALK.
5. IF THE CONTRACTOR ELECTS TO USE A CONSTRUCTION JOINT IN THE POURING OF THE PAVED DITCH, IT SHALL BE CONSTRUCTED AS DETAILED.
6. ANY LENGTH OF LONGITUDINAL REINFORCING STEEL WILL BE PERMITTED PROVIDED A 1'-0" LAP IS USED IN THE SPLICE. ADEQUATE TIES AT THE SPLICE SHALL BE REQUIRED.



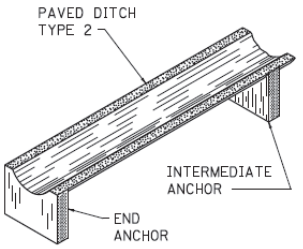
PLAN VIEW



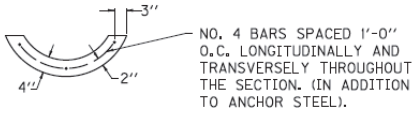
ELEVATION VIEW



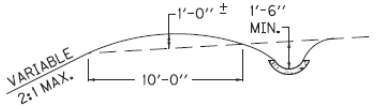
SECTION A-A



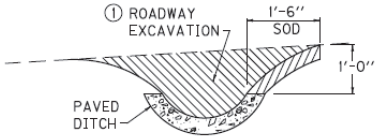
ISOMETRIC VIEW



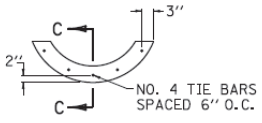
SECTION B-B



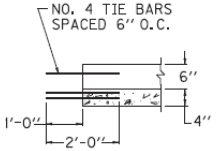
TYPICAL PAVED DITCH
(INTERCEPTOR DITCH)



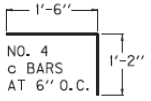
SHOULD THE TERRAIN OF THE EXISTING GROUND BE SO THAT WATER WOULD DRAIN INTO THE DITCH FROM BOTH SIDES, THEN SODDING WILL BE REQUIRED ON BOTH SIDES OF THE DITCH.



TIE BAR SECTIONAL VIEW



SECTION C-C



c BAR DETAIL

APPROX. STEEL QUANTITIES FOR MINIMUM SECTION SHOWN	
END ANCHORS (EACH)	8.90 LBS.
INTERMEDIATE ANCHORS (EACH)	8.90 LBS.
CONSTRUCTION JOINTS (EACH)	6.68 LBS.
BARS PER SQ. YD. OF DITCH	12.47 LBS.

KENTUCKY DEPARTMENT OF HIGHWAYS

PAVED DITCH TYPE 2

STANDARD DRAWING NO. RDD-002-06

SUBMITTED: DIRECTOR DIVISION OF DESIGN — DATE 12-1-99

APPROVED: STATE HIGHWAY ENGINEER — DATE 12-1-99

Figure 6: Pennsylvania Department of Transportation Standard Drawing:

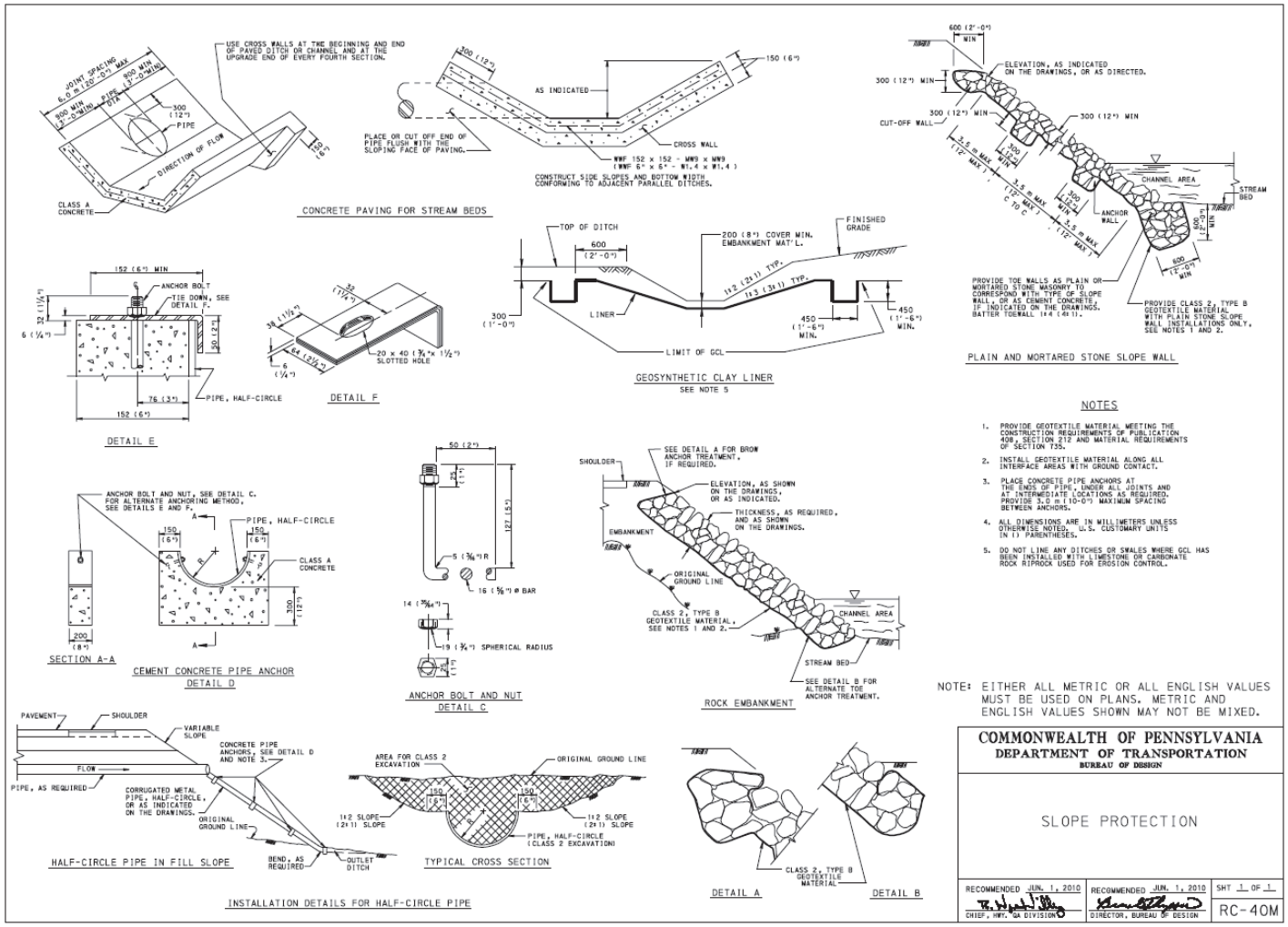


Figure 7: Michigan Department of Transportation Standard Drawing:

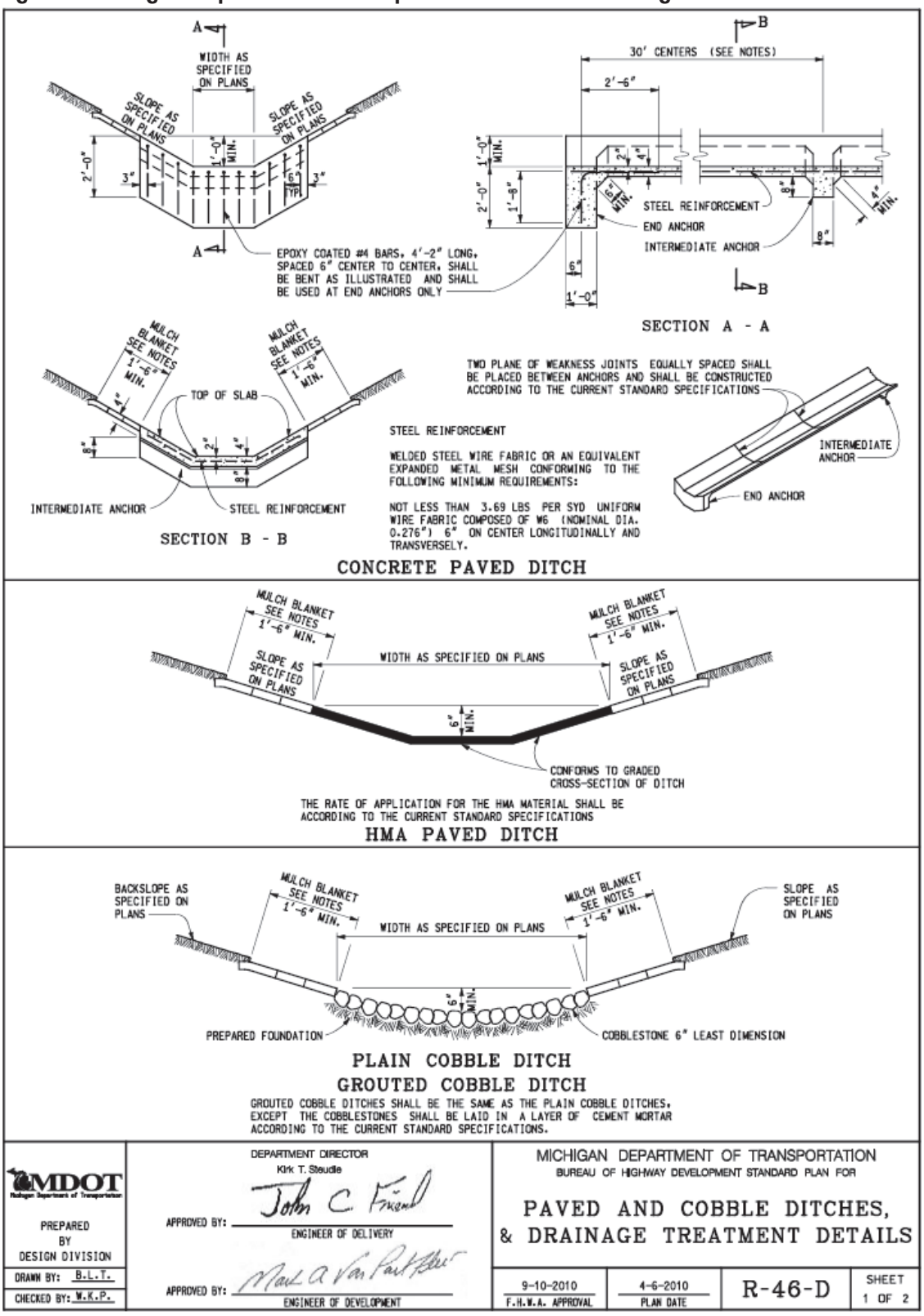
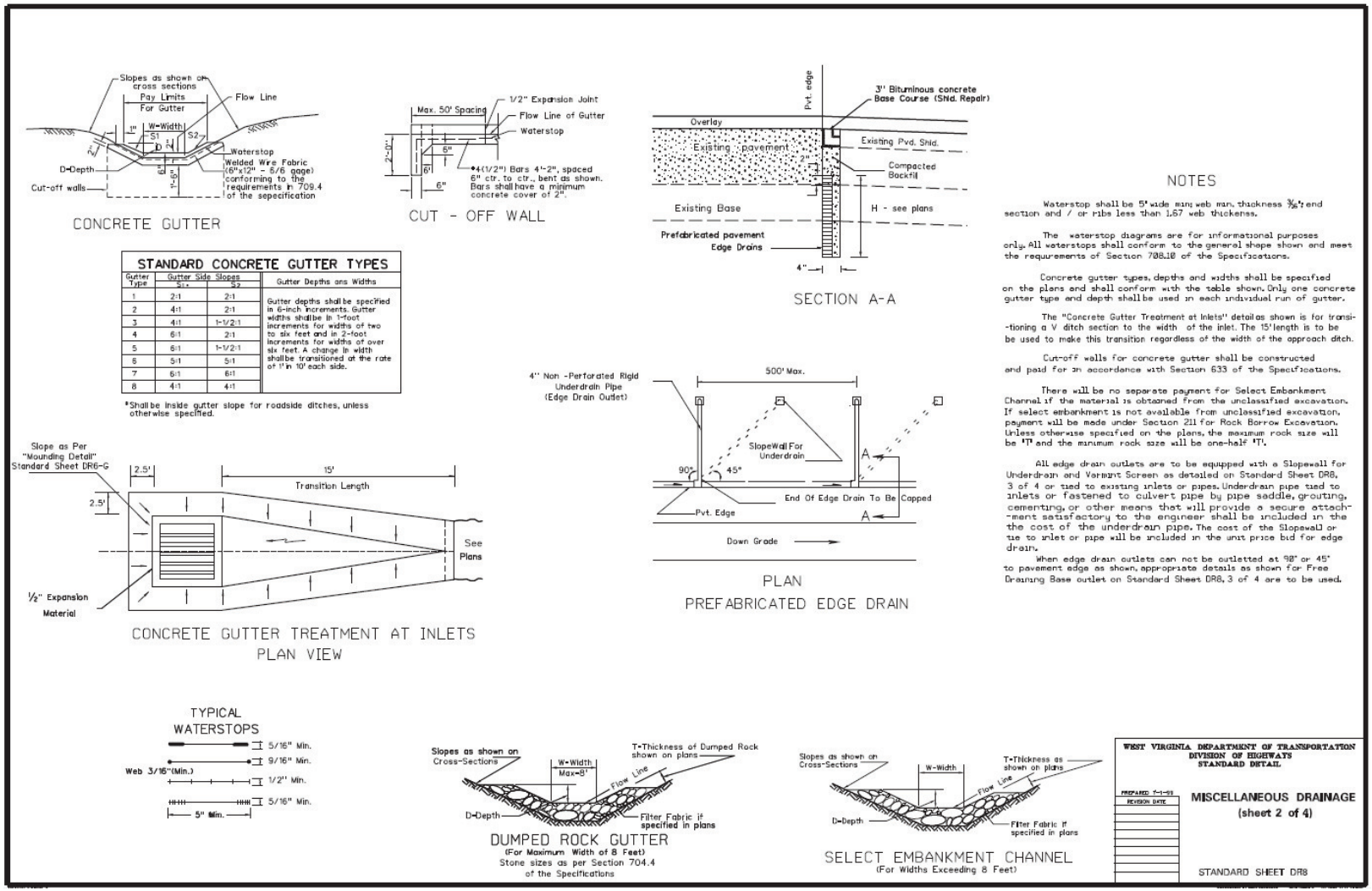


Figure 8: West Virginia Division of Highways Standard Drawing:



APPENDIX B:

Survey

The research team prepared an electronic survey using the Survey Monkey web application to solicit feedback on the construction and maintenance of roadside gutter systems. Invitations to complete the questionnaire were sent to the ListServ participants on the Transportation Research Advisory Committee (RAC), ten (10) Ohio County Engineer's Offices, and four (4) Ohio concrete contractors with ODOT experience. Raw results of the survey questionnaire are included at the end of this document.

A total of 24 responses were collected from public agency staff, and 4 responses from private contractors during the months of September and October 2017. The respondents represented a range of public agency employees, including highway, road and bridge maintenance mangers and superintendents, highway and state maintenance engineers, project managers, bridge inspectors and stormwater compliance managers, along with private contractors. The respondents had experience with installing and maintaining primarily Cast-in place concrete (21 respondents), but also asphalt (8 respondents), tied block mats (Flexamat) (6 respondents), articulating concrete blocks (2 respondents) and Concrete Cloth (2 respondents).

Cast-in-place concrete

The ease of working with cast-in-place concrete was reported in a wide range from easy (4 respondents) to difficult (1 respondent) to install.

The advantages of using cast-in-place concrete included:

- When problems occur they are normally easy to identify, which allows for maintenance to be scheduled.
- Appearance and longevity of material if constructed properly
- Effective for small project with the use of hand tools
- Easy to maintain and remove accumulated sediment/debris.
- Material holds up to snow plowing operations (Curb and gutter in municipalities)
- Elevations are easy to control (Curb and gutter in municipalities)
- Easy to establish and maintain a consistent grade.

The disadvantages of using cast-in-place concrete include:

- Installation is more difficult as compared to asphalt, articulating concrete blocks and tied block mats.
- Cast-in-place concrete paved ditches are notorious for being undermined. (Kentucky DOT)
- An expensive operation, requiring access to be constructed to get the equipment, materials and concrete mix to the site.
- May involve the use of concrete pumps.
- Rigidity of the system that leads to failures. (Kentucky DOT)

General Comments:

- Preparing the area is key. You have to get the grades, forms & base materials correct to get a good job.
- Five (5) respondents reported incorporating fiber reinforcement into the concrete mix design. While several organizations that incorporate fiber reinforcement in the mix design were not clear if the fiber reinforcement made a positive difference, three respondents thought that fiber reinforcement was beneficial.

Respondents were asked their experience and process for installing the cast-in-place concrete, including any special equipment used for milling and slipforming.

- Some contractors will try to slip form the gutter. This also depends on the location of the gutter and if they can physically get the equipment into those areas. Our gutters are cast-in-place by hand.
- Concrete is often poured by hand, but sometimes pumped.
- One response: crew excavates rough width and depth of gutter system. Bedding (gravel) placed in six-inch lift, metal or wooden rails set to appropriate profile slope, and wooden template of gutter shape constructed. During concrete pour a stiff mix is used and template pulled following rails. One or two members finish trowel, joint and broom finish (if called for on plan) concrete gutter. Large radii used in areas where gutters bend or turn. Outside portion of gutter is extended up slope to prevent potential erosion alongside gutter system.

Asphalt

The ease of working with asphalt was reported in a range from easy (1 respondent) to moderately difficult (7 respondents).

The advantages of using asphalt included:

- Asphalt is easier to repair than concrete
- Asphalt can be sealed with a slurry seal if needed
- Easy set up and cure time

The disadvantages of using asphalt include:

- Asphalt is labor intensive and often difficult
- Rollers often don't fit
- Plate compactors put a huge strain on the work force.

Tied Block Mats (Flexamat)

The ease of working with tied block mats was reported in a range from easy (3 respondents) to moderately difficult (1 respondent) to install.

The advantages of using tied block mats (Flexamat) included:

- Fits contours better (Kentucky DOT)
- Less likely to get undermined. (Kentucky DOT) (Answer conflicts with a below negative response)
- Flex-mat is used for problem areas that were not identified in construction and performs well. (Mississippi DOT)
- We utilize Flex-mat for ditch with scour and erosion issues and have had success with it. Fabric liners have been used as a temporary stabilizer. (Mississippi DOT)
- The Flex-mat saved a lot of cost and provides an adequate fix in most cases for maintenance forces. (Mississippi DOT)
- Smaller equipment, less preparation, less labor, easier installation. (Answer conflicts with a below negative response) (Trucco)

The disadvantages of using tied block mats (Flexamat) included:

- Difficult to maintain and repair.

- In higher flows they tend to roll up or washout. If anchored correctly, flow can still get under mat and creates scour holes. Grade then becomes varied, flow more turbulent, and slope/bank erosion starts.
- In flat profiles mat is very difficult to maintain grade. Over time sediment builds on top of mat and removal of accumulated sediment is difficult. Silt removal usually results in damage or removal of concrete mat system - requiring new installation. Mat usually requires twice the work making long-term costs higher than concrete.
- A significant amount of handwork and raking is necessary to prepare gutter grade because matting takes shape of what has been excavated.
- Depending upon size of mat, specialized equipment maybe necessary to transport and install mat system.
- All above disadvantages provided by Butler County, OH.

Articulating concrete blocks

A total of four (4) contractors rated articulating concrete blocks as moderately easy to install.

The advantages of using articulating concrete blocks included:

- Easier to install than asphalt and cast-in-place concrete.

No disadvantages were listed in the survey.

Concrete Cloth

The ease of working with Concrete Cloth was reported in a range from moderately easy (1 respondent) to difficult (1 respondent) to install. Product appears to be too new to the market for a complete understanding of its viability in this application.

The advantages of using Concrete Cloth included:

- New Innovations, Concrete fabric is fairly easy to install – much like laying lawn sod: roll it out and wet it, and you are done.

No disadvantages were listed in the survey.

Miscellaneous

Respondents were asked to describe their experience and process of installation, including special equipment, for non-concrete paved gutter materials.

- Bituminous pavements have been installed using 8-10' highway pavers, with an inverted crown
- Used an attachment to the bottom of a grader blade to make a depression in the asphalt for the water to flow in.
- Depending on the gutter location it can be difficult to get the equipment into tight areas.
- Small crane
- Concrete mat installation: excavate channel in shape of proposed gutter shape. Grading must be exact because matting takes shape of what has been excavated. A significant amount of handwork and raking is necessary to prepare gutter grade. Depending upon size of mat, specialized equipment maybe necessary to transport & install mat system. Typically soil is placed

on top and brushed across mat in preparation for seed/straw. Establishment of vegetation is difficult, if not impossible due to hard conditions or poor soils.

Respondents were asked to identify solutions to reduce time and/or expense with ditch protection, with respect to labor, materials, equipment, means and/or methods. These solutions included:

- Using fiber mats and having natural vegetation is a good solution for roadside ditches.
- New Innovations, Concrete fabric is fairly easy to install, much like laying lawn sod. Roll it out and wet it... you're done!
- For roadside ditches, erosion control materials appropriate for the amount of flow and the velocity are used. For high flow areas, rock dams are used to slow the water along with erosion blankets.
- We use fabric or mulch.
- We have purchased a wheeled excavator for cleaning out concrete lined channels. The wheels allow for it to be moved on its own without damaging roadways.
- Channel lining has performed very well.
- # 2 stone used in the ditch and on the banks to eliminate erosion on a limited basis.
- Cast-in-place concrete gutter system is best at reducing all the above aspects.

Respondents were asked for suggestions for rehabilitating existing paved gutters. These responses included:

- We have taken some of the paved ditches back to stone, hoe rammed and left in place, adding Limestone Channel Lining to protect the ditches. (3 respondents)
- Only cut out what requires full replacement if possible. We often dowel into up and down stream gutter to limit settlement and heaving.

Respondents were asked for suggestions for addressing channel erosion in existing roadside ditches. These suggestions included:

- Place rock check dams more frequently through ditch channel to slow down the water flow.
- Identify soil types, grades & surface water velocity and design accordingly
- Install fabric and stone in our maintenance operations.
- Use a lot of rock or install the pre-fabricated kinds.
- Placing proper erosion remediation devices can help prevent these issues.
- Weir type structures
- Use spalls and compact in place
- Use rip rap, or contract for concrete lined channels.
- A liner with appropriate rock over the top works well for higher velocity areas.
- Fabric, geotextile, rock
- In very extreme conditions, we have used stepped gabion baskets.
- Rock Channel Protection (RCP) with a thin slurry of concrete. Need to anchor in toe and upstream end of RCP to prevent undermining of RCP slurry.

Respondents were asked to identify their preferred material for paved gutter applications:

- Cast-in-place concrete = 9
- Asphalt = 2 (Washington DOT, Utah DOT)
- Tied Block Mat (Flexamat) = 2 (Kentucky DOT)
- Articulating concrete block mat = 0
- Concrete Cloth = 1 (Washington DOT)

Summary of Reported Ease/Difficulty of Installation for Each Material Type
(value represents number of responses received for each difficulty rating)

	Easy to install	**Moderately easy to install**	**Moderately difficult to install**	**Difficult to install**	**Respondent**
Cast-in-place concrete	3 (responses)	7	5	1	Agency / Owner
	1	1	2	0	Contractor
Asphalt	1	3	6	0	Agency / Owner
	0	0	1	0	Contractor
Articulating concrete blocks	0	3	0	0	Agency / Owner
	0	1	0	0	Contractor
Tied block mat (Flexamat)	1	2	1	0	Agency / Owner
	2	0	0	0	Contractor
Concrete Cloth	0	1	0	0	Agency / Owner
	0	0	0	1	Contractor

Q1 Respondent contact information.

Answered: 23 Skipped: 1

ANSWER CHOICES	RESPONSES	
Name	100.00%	23
Company	100.00%	23
Address	0.00%	0
Address 2	0.00%	0
City/Town	0.00%	0
State/Province	0.00%	0
ZIP/Postal Code	0.00%	0
Country	0.00%	0
Email Address	100.00%	23
Phone Number	91.30%	21

#	NAME	DATE
1	Brad Burge	10/11/2017 11:49 AM
2	Eric Pottenger	10/4/2017 12:49 PM
3	Butch Helmling	10/3/2017 6:51 AM
4	Raul Amavisca, PE	10/2/2017 6:42 PM
5	Wheeler Nevels	9/29/2017 9:31 AM
6	Virgil Hawkins	9/28/2017 2:11 PM
7	Heath Patterson	9/28/2017 1:54 PM
8	David Olsonawski	9/28/2017 12:52 PM
9	Stephen Schnieder	9/28/2017 11:27 AM
10	Tommy Thompson	9/28/2017 10:32 AM
11	Steve Mefford	9/28/2017 8:27 AM
12	Scott Wilcox	9/27/2017 6:17 PM
13	mike golden	9/27/2017 5:37 PM
14	Kevin Rust	9/27/2017 4:47 PM
15	Jim Henderson	9/27/2017 4:03 PM
16	Kevin Griffin	9/27/2017 10:42 AM
17	David L Koontz	9/26/2017 3:07 PM
18	Kenneth Siri	9/26/2017 2:53 PM
19	Rex Yarger	9/26/2017 2:12 PM
20	Lawrence Fulton	9/26/2017 1:31 PM
21	Ken McCarty	9/26/2017 1:28 PM
22	Shaun DeForest	9/26/2017 8:20 AM

23	Jason Van Nice	9/25/2017 3:32 PM
#	**COMPANY**	**DATE**
1	Nevada Department of Transportation	10/11/2017 11:49 AM
2	Butler County Storm Water District	10/4/2017 12:49 PM
3	Portage County Engineer	10/3/2017 6:51 AM
4	AZ Dept of Transportation	10/2/2017 6:42 PM
5	Commonwealth of Kentucky	9/29/2017 9:31 AM
6	Wright County Highway Department	9/28/2017 2:11 PM
7	Miss. Dept. of Transportation	9/28/2017 1:54 PM
8	Hubbard County	9/28/2017 12:52 PM
9	Nobles County	9/28/2017 11:27 AM
10	Nevada Dept. of Transportation	9/28/2017 10:32 AM
11	Iowa DOT	9/28/2017 8:27 AM
12	WSDOT (Washington State)	9/27/2017 6:17 PM
13	wsdot	9/27/2017 5:37 PM
14	KYTC	9/27/2017 4:47 PM
15	WSDOT	9/27/2017 4:03 PM
16	UDOT	9/27/2017 10:42 AM
17	Summit County Engineer	9/26/2017 3:07 PM
18	NDOT	9/26/2017 2:53 PM
19	Richland County Engineer's office	9/26/2017 2:12 PM
20	Summit County Engineer	9/26/2017 1:31 PM
21	KYTC, D6	9/26/2017 1:28 PM
22	Nevada Department of Transportation	9/26/2017 8:20 AM
23	Kansas DOT	9/25/2017 3:32 PM
#	**ADDRESS**	**DATE**
	There are no responses.	
#	**ADDRESS 2**	**DATE**
	There are no responses.	
#	**CITY/TOWN**	**DATE**
	There are no responses.	
#	**STATE/PROVINCE**	**DATE**
	There are no responses.	
#	**ZIP/POSTAL CODE**	**DATE**
	There are no responses.	
#	**COUNTRY**	**DATE**
	There are no responses.	
#	**EMAIL ADDRESS**	**DATE**
1	bburge@dot.nv.gov	10/11/2017 11:49 AM
2	pottengere@bceo.org	10/4/2017 12:49 PM
3	bhelmling@portageco.com	10/3/2017 6:51 AM

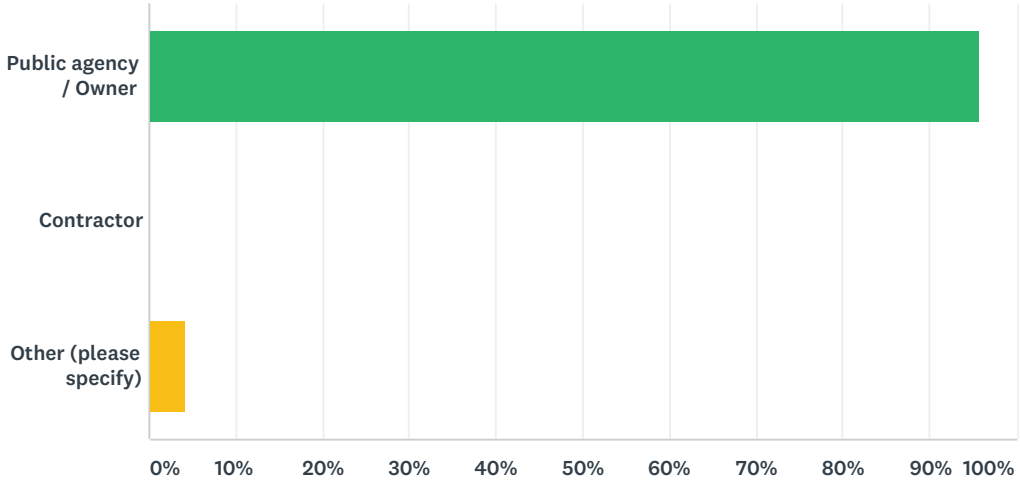
4	Ramavisca@azdot.gov	10/2/2017 6:42 PM
5	wheeler.nevels@ky.gov	9/29/2017 9:31 AM
6	virgil.hawkins@co.wright.mn.us	9/28/2017 2:11 PM
7	hpatterson@mdot.ms.gov	9/28/2017 1:54 PM
8	dolsonawski@co.hubbard.mn.us	9/28/2017 12:52 PM
9	sschnieder@co.nobles.mn.us	9/28/2017 11:27 AM
10	tthompson@dot.nv.gov	9/28/2017 10:32 AM
11	stpehen.mefford@iowadot.us	9/28/2017 8:27 AM
12	wilcoxs@wsdot.wa.gov	9/27/2017 6:17 PM
13	goldenm@wsdot.wa.gov	9/27/2017 5:37 PM
14	kevin.rust@ky.gov	9/27/2017 4:47 PM
15	henderj@wsdot.wa.gov	9/27/2017 4:03 PM
16	kgriffin@utah.gov	9/27/2017 10:42 AM
17	dkoontz@summitengineer.net	9/26/2017 3:07 PM
18	ksiri@dot.nv.gov	9/26/2017 2:53 PM
19	RYARGER@RCENGINEER.COM	9/26/2017 2:12 PM
20	lfulton@summitengineer.net	9/26/2017 1:31 PM
21	ken.mccarty@ky.gov	9/26/2017 1:28 PM
22	sdeforest@dot.nv.gov	9/26/2017 8:20 AM
23	jason.vannice@ks.gov	9/25/2017 3:32 PM

#	PHONE NUMBER	DATE
1	513.785.4121	10/4/2017 12:49 PM
2	3302966411	10/3/2017 6:51 AM
3	602-712-8965	10/2/2017 6:42 PM
4	5023304091	9/29/2017 9:31 AM
5	763-682-7388	9/28/2017 2:11 PM
6	601-359-7113	9/28/2017 1:54 PM
7	2187323302	9/28/2017 12:52 PM
8	507-295-5322	9/28/2017 11:27 AM
9	702 385-6500	9/28/2017 10:32 AM
10	(360) 740-8642	9/27/2017 6:17 PM
11	253 372-3900	9/27/2017 5:37 PM
12	859-341-2700	9/27/2017 4:47 PM
13	509 577-1960	9/27/2017 4:03 PM
14	801-965-4120	9/27/2017 10:42 AM
15	330-643-8537	9/26/2017 3:07 PM
16	775-482-2379	9/26/2017 2:53 PM
17	4197745679	9/26/2017 2:12 PM
18	330-643-8458	9/26/2017 1:31 PM
19	859-743-1921	9/26/2017 1:28 PM
20	(775) 623-8000	9/26/2017 8:20 AM

21	785-250-4793	9/25/2017 3:32 PM

Q2 Which of the following best describes your organization?

Answered: 24 Skipped: 0



ANSWER CHOICES	RESPONSES	
Public agency / Owner	95.83%	23
Contractor	0.00%	0
Other (please specify)	4.17%	1
TOTAL		24

#	OTHER (PLEASE SPECIFY)	DATE
1	State of nevada	9/26/2017 8:20 AM

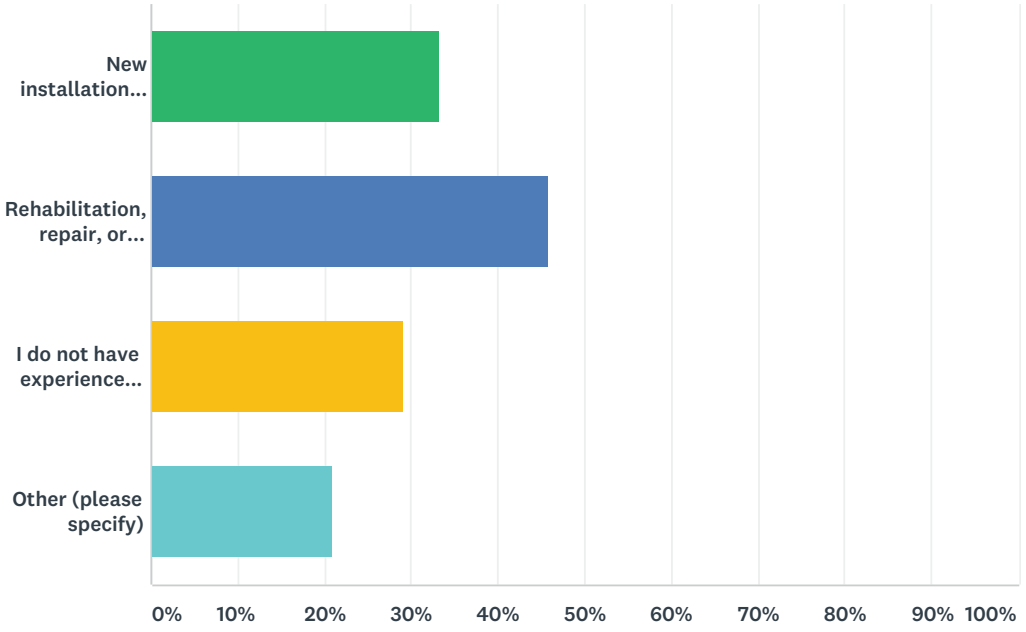
Q3 What is your role in your organization?

Answered: 24 Skipped: 0

#	RESPONSES	DATE
1	Highway Maintenance Manager	10/11/2017 11:49 AM
2	Development Services / Storm Water Management	10/4/2017 12:49 PM
3	General Superintendent for Road & Bridge Maintenance	10/3/2017 6:51 AM
4	Direct maintenance activities in Phoenix area for ADOT	10/2/2017 6:42 PM
5	midmanagement	9/29/2017 9:31 AM
6	Highway Engineer	9/28/2017 2:11 PM
7	State Maintenance Engineering	9/28/2017 1:54 PM
8	Highway Engineer, Public Works Coordinator	9/28/2017 12:52 PM
9	Public Works Director	9/28/2017 11:27 AM
10	Highway Maintenance Manager	9/28/2017 10:32 AM
11	District 4 Operations Manager	9/28/2017 8:27 AM
12	Superintendent	9/28/2017 8:23 AM
13	Maintenance & Operations Superintendent	9/27/2017 6:17 PM
14	Maint Supt	9/27/2017 5:37 PM
15	Engineering Manager	9/27/2017 4:47 PM
16	Maint Supt	9/27/2017 4:03 PM
17	Director of Maintenance	9/27/2017 10:42 AM
18	Engineering Project Manager	9/26/2017 3:07 PM
19	Maintenance Manager	9/26/2017 2:53 PM
20	DEPUTY ENGINEER, BRIDGE INSPECTOR	9/26/2017 2:12 PM
21	Chief Deputy Engineer	9/26/2017 1:31 PM
22	Maintenance Engineer Tech Supervisor	9/26/2017 1:28 PM
23	Highway maintenance manager	9/26/2017 8:20 AM
24	Stormwater Compliance Manager	9/25/2017 3:32 PM

Q4 Which of the following statements describe your experience constructing paved gutters...

Answered: 24 Skipped: 0

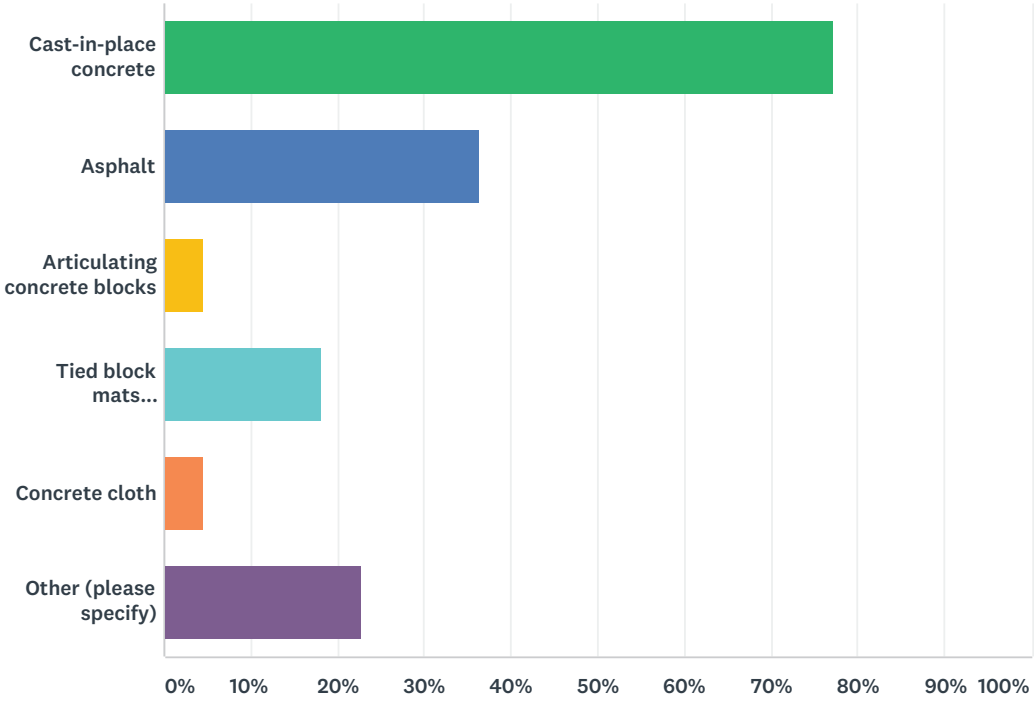


ANSWER CHOICES	RESPONSES	
New installation of concrete ditch lining used for roadside drainage.	33.33%	8
Rehabilitation, repair, or replacement of concrete ditch lining used for roadside drainage.	45.83%	11
I do not have experience constructing paved gutter systems.	29.17%	7
Other (please specify)	20.83%	5
Total Respondents: 24		

#	OTHER (PLEASE SPECIFY)	DATE
1	Detention basin low flow gutter systems	10/4/2017 12:50 PM
2	They are only present on County Roads that were at one time State Hwys.	10/3/2017 6:53 AM
3	Use concrete curb and gutter in municipalities	9/28/2017 11:29 AM
4	minor repairs	9/27/2017 4:06 PM
5	We do not construct these ditches. A contractor would construct these. We would on the other hand we maintain them once completed	9/26/2017 8:23 AM

Q5 What materials have you used in the construction of paved gutters?

Answered: 22 Skipped: 2

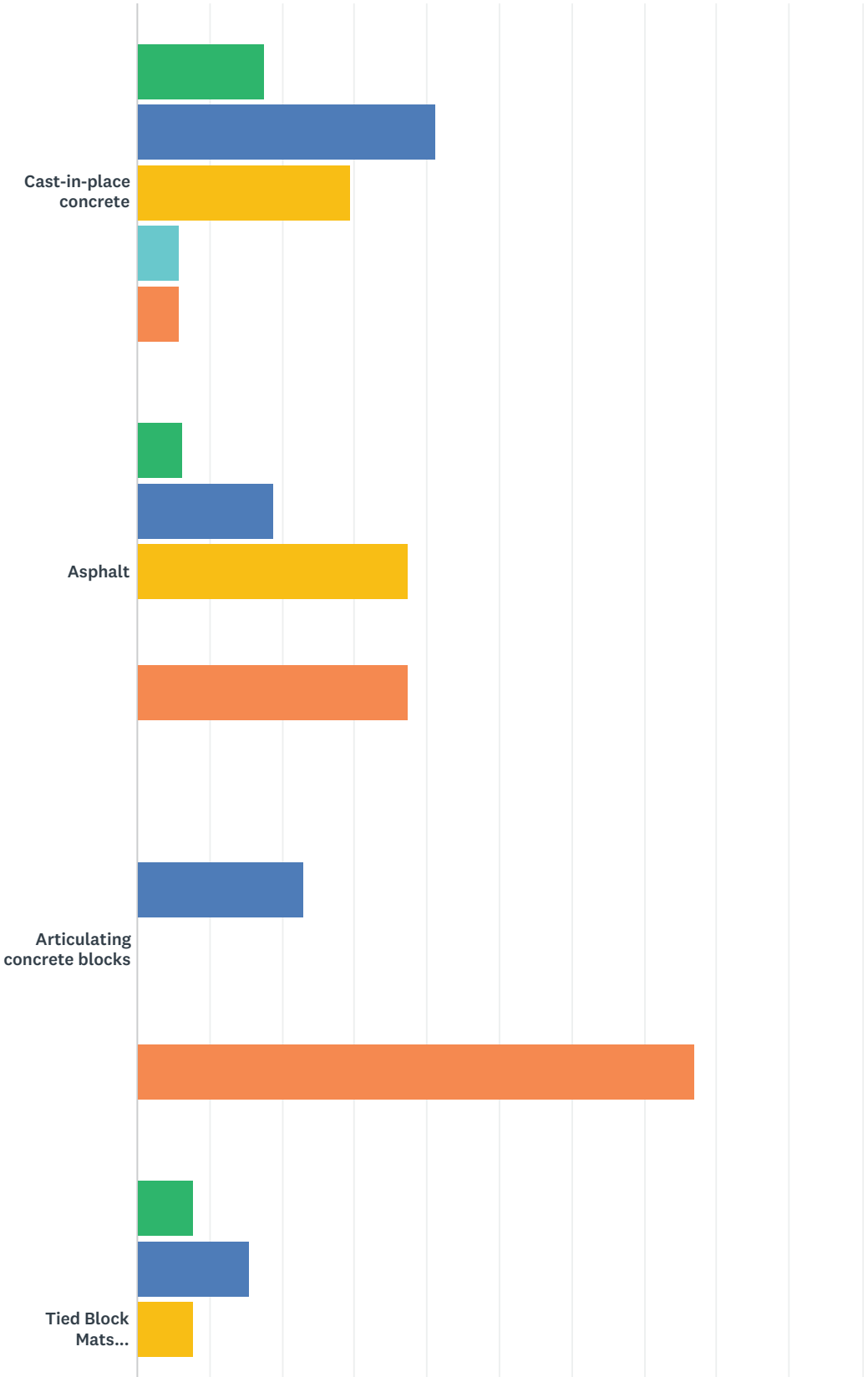


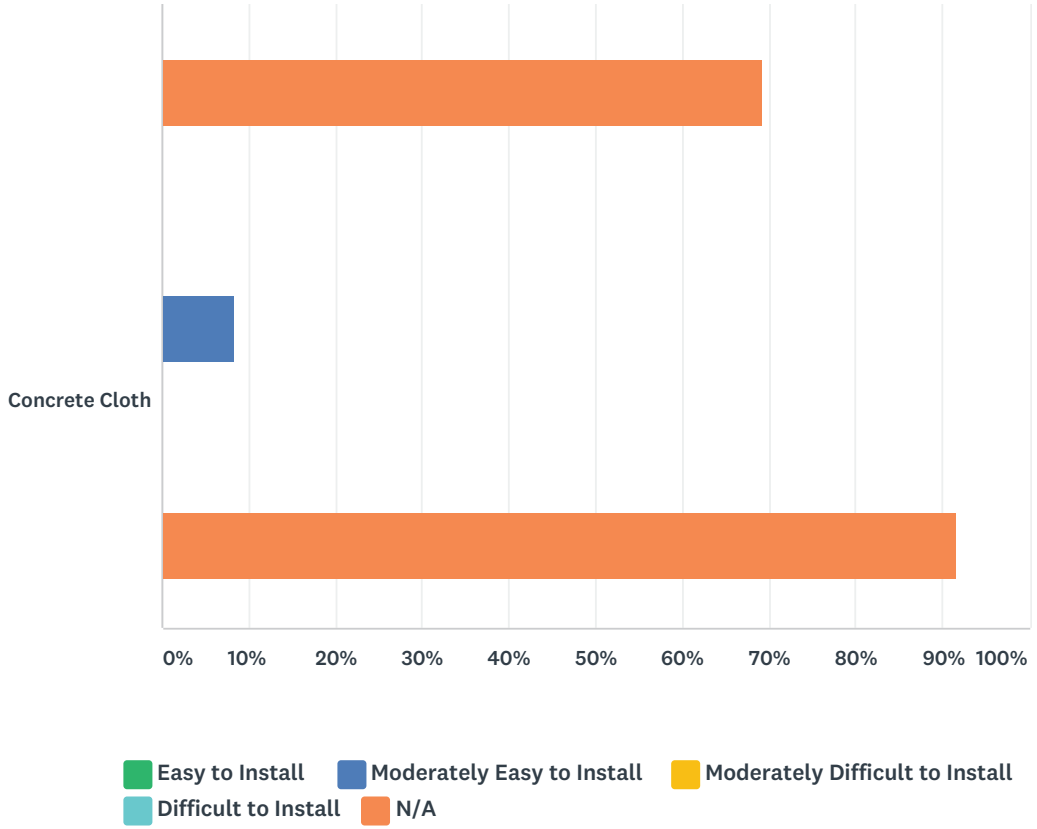
ANSWER CHOICES	RESPONSES	
Cast-in-place concrete	77.27%	17
Asphalt	36.36%	8
Articulating concrete blocks	4.55%	1
Tied block mats (Flex-a-mat)	18.18%	4
Concrete cloth	4.55%	1
Other (please specify)	22.73%	5
Total Respondents: 22		

#	OTHER (PLEASE SPECIFY)	DATE
1	None	10/3/2017 6:53 AM
2	Never constructed a paved gutter	9/28/2017 10:33 AM
3	NA	9/28/2017 8:23 AM
4	None	9/26/2017 2:54 PM
5	we do not construct these, we maintain them	9/26/2017 8:23 AM

Q6 Please rate the materials you have used in constructing paved gutters according to ease of installation.

Answered: 18 Skipped: 6





	EASY TO INSTALL	MODERATELY EASY TO INSTALL	MODERATELY DIFFICULT TO INSTALL	DIFFICULT TO INSTALL	N/A	TOTAL
Cast-in-place concrete	17.65% 3	41.18% 7	29.41% 5	5.88% 1	5.88% 1	17
Asphalt	6.25% 1	18.75% 3	37.50% 6	0.00% 0	37.50% 6	16
Articulating concrete blocks	0.00% 0	23.08% 3	0.00% 0	0.00% 0	76.92% 10	13
Tied Block Mats (Flex-a-mat)	7.69% 1	15.38% 2	7.69% 1	0.00% 0	69.23% 9	13
Concrete Cloth	0.00% 0	8.33% 1	0.00% 0	0.00% 0	91.67% 11	12

#	OTHER (PLEASE SPECIFY)	DATE
1	NA	10/3/2017 6:53 AM
2	Kentucky has used cast-in-place concrete for paved ditches. In general, this is a poor idea for long term performance.	9/29/2017 9:40 AM
3	N/A	9/28/2017 10:35 AM
4	NA	9/28/2017 8:23 AM
5	Asphalt is labor intensive and often difficult	9/27/2017 6:21 PM
6	None	9/26/2017 2:55 PM

Q7 What is your preferred material for paved gutter applications? Why?

Answered: 21 Skipped: 3

#	RESPONSES	DATE
1	Cast-in place concrete Durability and longevity	10/11/2017 11:51 AM
2	Concrete. Easy to establish and keep a consistent grade. Durable, easy to maintain and remove accumulated sediment/debris.	10/4/2017 12:57 PM
3	NA	10/3/2017 6:53 AM
4	Concrete because it's pretty stable and permanent.	10/2/2017 6:45 PM
5	If you're using gutter and ditch synonymously, we prefer channel lining.	9/29/2017 9:40 AM
6	N/A	9/28/2017 2:12 PM
7	Cast-in-place, more permanent installation. Flex-mat is used for problem areas that were not identified in construction and performs well.	9/28/2017 2:03 PM
8	We do not use them.	9/28/2017 12:54 PM
9	Concrete It is long lasting, holds up to smow plowing operations, easy to install, elevations are easy to control, has a good uniform apperance	9/28/2017 11:32 AM
10	N/A	9/28/2017 10:35 AM
11	Concrete cloth. www.nunainnovations.com	9/27/2017 6:21 PM
12	asphalt.. easy set up and cure time	9/27/2017 5:39 PM
13	Flex-a-mat. Fits contours better and less likely to get undermined.	9/27/2017 4:49 PM
14	No preference	9/27/2017 4:06 PM
15	Asphalt is easier to repair than concrete. It can also be seal with a slurry seal if needed.	9/27/2017 10:45 AM
16	Concrete - less maintenance	9/26/2017 2:55 PM
17	From what I have read, I would try articulating concrete blocks.	9/26/2017 2:17 PM
18	depends on the application, flex-mat	9/26/2017 1:34 PM
19	Concrete works well, maintaining the proper drainage is an ongoing issue	9/26/2017 1:34 PM
20	concrete, appearance and longevity of material if constructed properly	9/26/2017 8:24 AM
21	cast in place concrete; It is effective and many contractors have the capability to construct it. When problems occur they are normally easy to identify which allows for maintenance to be scheduled.	9/25/2017 3:35 PM

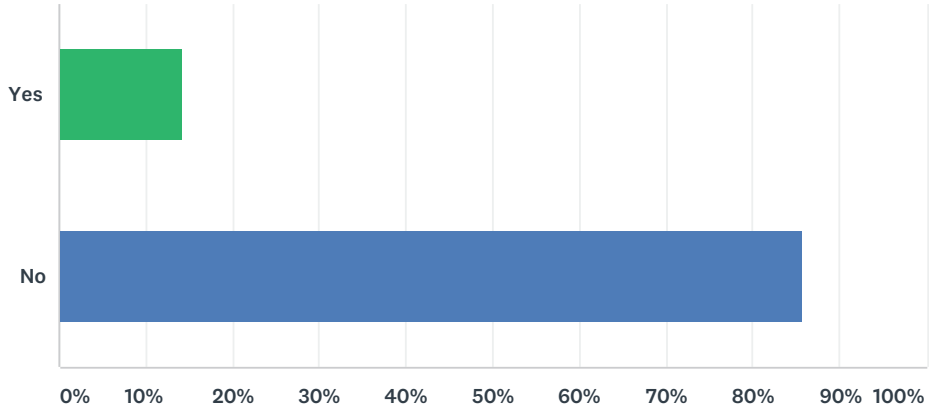
Q8 Have you identified materials that you would not utilize in paved gutter applications due to prior poor performance? Please describe?

Answered: 19 Skipped: 5

#	RESPONSES	DATE
1	Tied block mats have been difficult to install, maintain and repair. In higher flows they tend to roll up or washout. If anchored correctly, flow can still get under mat and creates scour holes. Grade then becomes varied, flow more turbulent, and slope/bank erosion starts. In flat profiles mat is very difficult to maintain grade. Over time sediment builds on top of mat and removal of accumulated sediment is difficult. Silt removal usually results in damage or removal of concrete mat system - requiring new installation. Mat usually requires twice the work making long-term costs higher than concrete.	10/4/2017 12:57 PM
2	We maintain what was built - which was concrete.	10/2/2017 6:45 PM
3	Cast-in-place concrete paved ditches are notorious for being undermined.	9/29/2017 9:40 AM
4	N/A	9/28/2017 2:12 PM
5	None	9/28/2017 2:03 PM
6	NA	9/28/2017 12:54 PM
7	Bituminous curbs to hold the water in the gutter	9/28/2017 11:32 AM
8	N/A	9/28/2017 10:35 AM
9	Not specifically	9/27/2017 6:21 PM
10	no	9/27/2017 5:39 PM
11	Small channel lining. Moves under heavy storms.	9/27/2017 4:49 PM
12	No experience	9/27/2017 4:06 PM
13	None	9/27/2017 10:45 AM
14	No	9/26/2017 2:55 PM
15	no	9/26/2017 2:17 PM
16	no, poor perfromance has been based on poor installation	9/26/2017 1:34 PM
17	Highly flexible pavements haven't preformed well in my career	9/26/2017 1:34 PM
18	none	9/26/2017 8:24 AM
19	no	9/25/2017 3:35 PM

Q9 For cast-in-place concrete paved gutters, have you used mix designs other than 4,000 psi compressive strength with air entrainment?

Answered: 21 Skipped: 3



ANSWER CHOICES	RESPONSES	
Yes	14.29%	3
No	85.71%	18
TOTAL		21

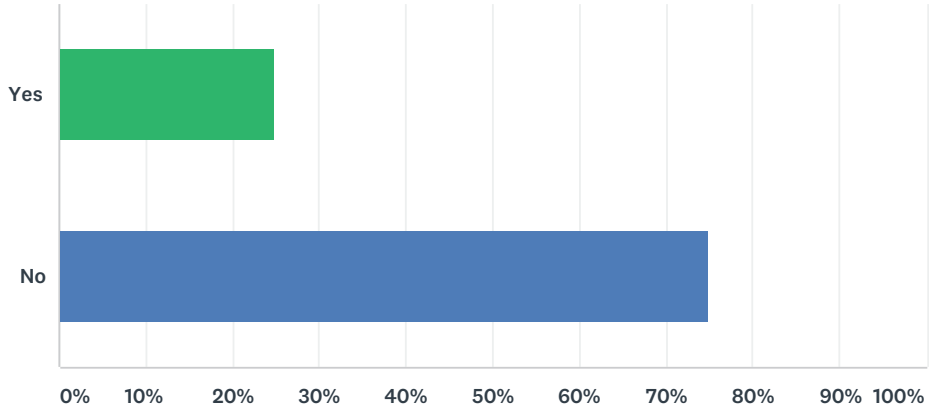
Q10 If your answer to the prior question was yes, please elaborate on the mix specifications and note any positive or negative experiences using the alternate concrete mix, both during initial construction and long term performance.

Answered: 6 Skipped: 18

#	RESPONSES	DATE
1	NA	10/3/2017 6:54 AM
2	Kentucky would use 3500 psi concrete. The strength isn't the problem. It's the rigidity of the system that leads to failures.	9/29/2017 9:42 AM
3	NA	9/28/2017 11:32 AM
4	3500. Nothing wrong with the mix, they just get undermined.	9/27/2017 4:50 PM
5	NA	9/27/2017 10:45 AM
6	Typically we specify "Grade 3.0" or 3000 psi air entrained concrete.	9/25/2017 3:40 PM

Q11 For cast-in-place concrete paved gutters, have you incorporated fiber reinforcement in the mix design?

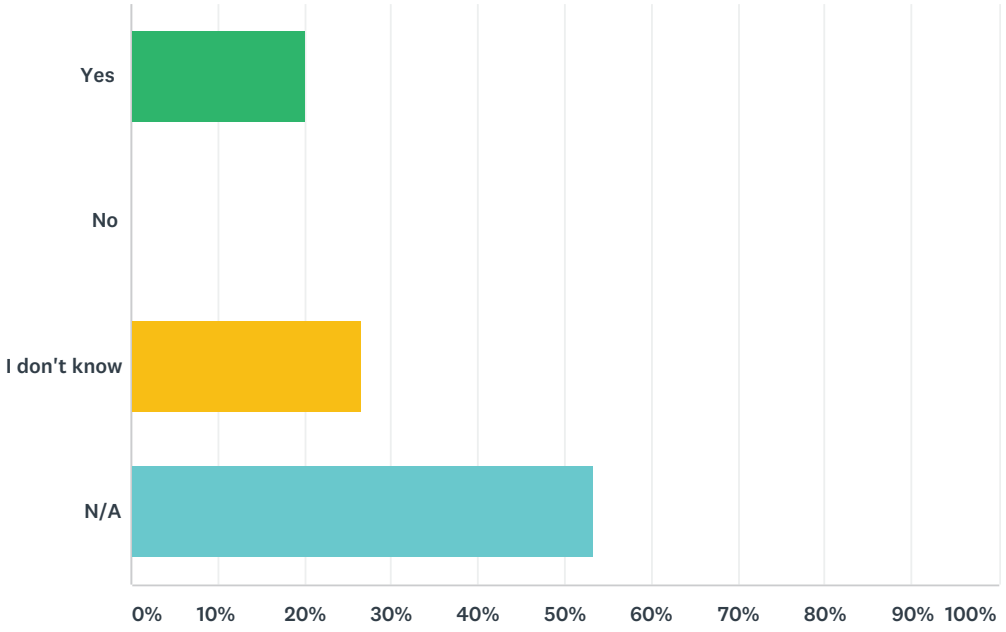
Answered: 20 Skipped: 4



ANSWER CHOICES	RESPONSES	
Yes	25.00%	5
No	75.00%	15
TOTAL		20

Q12 If your answer to the prior question was yes, have you found the fiber reinforcement to be beneficial?

Answered: 15 Skipped: 9



ANSWER CHOICES	RESPONSES	
Yes	20.00%	3
No	0.00%	0
I don't know	26.67%	4
N/A	53.33%	8
TOTAL		15

Q13 For cast-in-place concrete paved gutters, please describe your experience and process for installing the concrete, including any special equipment used for milling and slipforming.

Answered: 15 Skipped: 9

#	RESPONSES	DATE
1	Very positive experience. Crew excavates rough width and depth of gutter system. Bedding (gravel) placed in six-inch lift, metal or wooden rails set to appropriate profile slope, and wooden template of gutter shape constructed. During concrete pour a stiff mix is used and template pulled following rails. One or two members finish trowel, joint and broom finish (if called for on plan) concrete gutter. Large radii used in areas where gutter bends or turns, and outside portion of gutter is extended up slope to prevent potential erosion alongside gutter system.	10/4/2017 1:08 PM
2	NA	10/3/2017 6:55 AM
3	My experience is mostly repair of spalls such that forms are used. It's not been installing new where we might have slip formed. Past experience with Caltrans, though, was where I saw median barriers slip formed.	10/2/2017 6:48 PM
4	N/A	9/29/2017 9:43 AM
5	Many use slip form for concrete vegetation pads under high tension cable barrier as a mow strip, but most paved pitch is cast-in-place.	9/28/2017 2:05 PM
6	na	9/28/2017 12:55 PM
7	Use standard curb adn gutter slip form machine. Have also use forms for smaller areas.	9/28/2017 11:33 AM
8	limited.. we are a maintenance org so we only do repairs	9/27/2017 5:39 PM
9	Poured by hand, sometimes pumped.	9/27/2017 4:50 PM
10	Only done repairs	9/27/2017 4:06 PM
11	Most contractors will try to slip form the gutter but this also depends on the location of the gutter and if they can physically get the equipment into those areas.	9/27/2017 10:46 AM
12	No experience	9/26/2017 2:56 PM
13	Preparing the area is key; have to get the grades, forms & base materials correct to get a good job.	9/26/2017 2:20 PM
14	I have been involved in estimating and installing, typical slip form paving machines have been used, I have seen simple milling attachments that mount to a motor grader as well as a mainline asphalt milling machine.	9/26/2017 1:37 PM
15	projects were rather small & were hand tools in place	9/26/2017 1:36 PM

Q14 For non-concrete paved gutter materials, please describe your experience and process for installation. Note if any special equipment was utilized to facilitate installation.

Answered: 17 Skipped: 7

#	RESPONSES	DATE
1	Concrete mat installation; excavate channel in shape of proposed gutter shape. Grading must be exact because matting takes shape of what has been excavated. A significant amount of handwork and raking is necessary to prepare gutter grade. Depending upon size of mat, specialized equipment maybe necessary to transport & install mat system. Typically soil is placed on top and brushed across mat in preparation for seed/straw. Establishment of vegetation is difficult, if not impossible due to hard conditions or poor soils.	10/4/2017 1:19 PM
2	NA	10/3/2017 6:55 AM
3	Only used concrete.	10/2/2017 6:48 PM
4	N/A	9/29/2017 9:43 AM
5	We utilize Flex-mat for ditch with scour and erosion issues and have had success with it. Fabric liners have been used as a temporary stabilizer.	9/28/2017 2:06 PM
6	na	9/28/2017 12:55 PM
7	NA	9/28/2017 11:33 AM
8	N/A	9/28/2017 10:35 AM
9	Hot Mix Asphalt, labor intensive, rollers often don't fit and plate compactors put a huge strain on the folks in our work force in these applications.	9/27/2017 6:24 PM
10	no special equipment for asphalt	9/27/2017 5:40 PM
11	Small crane.	9/27/2017 4:51 PM
12	no experience	9/27/2017 4:06 PM
13	This is the same as placing concrete. Depending on the gutter location it can be difficult to get the equipment into tight areas.	9/27/2017 10:47 AM
14	No experience	9/26/2017 2:58 PM
15	Used an attachment to the bottom of a grader blade to make a depression in the asphalt for the water to flow in.	9/26/2017 2:21 PM
16	Bituminous pavements have been installed using 8-10' highway pavers, with an inverted crown	9/26/2017 1:39 PM
17	small projects were installed primarily with hand tools	9/26/2017 1:36 PM

Q15 Have you identified solutions to reduce time and/or expense with ditch protection, with respect to labor, materials, equipment, means and/or methods? Please describe.

Answered: 18 Skipped: 6

#	RESPONSES	DATE
1	Pour in place concrete gutter system is best at reducing all the above aspects.	10/4/2017 1:23 PM
2	We have successfully used # 2 stone in the ditch and on the banks to eliminate erosion on a limited bases.	10/3/2017 6:59 AM
3	We have purchased as wheeled excavator for cleaning out concrete lined channels. The wheels allow for it to be moved on it's own without damaging roadways.	10/2/2017 6:51 PM
4	Channel lining has performed very well.	9/29/2017 9:46 AM
5	the Flex-mat saved a lot of cost and provides an adequate fix in most cases for maintenance forces.	9/28/2017 2:09 PM
6	we use fabric or mulch	9/28/2017 12:56 PM
7	For roadside ditches, erosoin control materials appropriate for the amount of flow and the velocity are used. FOr high flow areas, rock dams are used to slow the water along with erosoin blankets.	9/28/2017 11:37 AM
8	Not to my knowledge, only methods our maintenance divisions use is rip rap rock with concrete slurry to lock the rock in.	9/28/2017 10:37 AM
9	New Innovations Concrete fabric is fairly easy to install, much like laying lawn sod. Roll it our and wet it... your done!	9/27/2017 6:27 PM
10	no	9/27/2017 5:40 PM
11	No, not really.	9/27/2017 4:52 PM
12	No experience	9/27/2017 4:06 PM
13	Using fiber mats and having natural vegetation is a good solution for roadside ditches.	9/27/2017 10:49 AM
14	No	9/26/2017 3:02 PM
15	no	9/26/2017 2:24 PM
16	Good luck! Ditch maintenance is a nightmare...	9/26/2017 1:42 PM
17	no	9/26/2017 1:38 PM
18	no	9/26/2017 8:27 AM

Q16 Do you have any other suggestions for rehabilitating existing paved gutters?

Answered: 17 Skipped: 7

#	RESPONSES	DATE
1	Only cutout what requires full replacement if possible. We often dowel into up & down stream gutter to limit settlement and heaving.	10/4/2017 1:23 PM
2	NA	10/3/2017 6:59 AM
3	Perhaps oiling/sealing them like asphalt concrete on roadways is done?	10/2/2017 6:51 PM
4	Hoe ram the concrete into channel lining sized pieces.	9/29/2017 9:46 AM
5	no	9/28/2017 12:56 PM
6	No	9/28/2017 11:37 AM
7	No	9/28/2017 10:37 AM
8	Wish I did and would very much like to receive any other solutions this survey turns up !	9/27/2017 6:27 PM
9	no	9/27/2017 5:40 PM
10	Break and seat.	9/27/2017 4:52 PM
11	No experience	9/27/2017 4:06 PM
12	None	9/27/2017 10:49 AM
13	No	9/26/2017 3:02 PM
14	May need to just bust them up into rock channel protection.	9/26/2017 2:24 PM
15	We have taken some of the paved ditches back to stone, hoe rammed and left in place, adding Limestone Channel Lining to protect the ditches	9/26/2017 1:42 PM
16	make sure done in larger quantities	9/26/2017 1:38 PM
17	no	9/26/2017 8:27 AM

Q17 Do you have any other suggestions for addressing channel erosion in existing roadside ditches?

Answered: 16 Skipped: 8

#	RESPONSES	DATE
1	Rock Channel Protection (RCP) with a thin slurry of concrete. Need to anchor in toe and upstream end of RCP to prevent undermining of RCP slurry.	10/4/2017 1:23 PM
2	Concrete lining when installed by construction.	10/2/2017 6:51 PM
3	In very extreme conditions, we have used stepped gabion baskets.	9/29/2017 9:46 AM
4	fabric, geotextile, rock	9/28/2017 12:56 PM
5	A liner with apporpriate rock over the top works well for higher velocity areas.	9/28/2017 11:37 AM
6	Just the use of rip rap, or contract for concrete lined channels.	9/28/2017 10:37 AM
7	Heavy Maintenance Item in my area, also would appreciate any info this survey supplies.	9/27/2017 6:27 PM
8	we use spalls and compact in place	9/27/2017 5:40 PM
9	Weir type structures, maybe.	9/27/2017 4:52 PM
10	Placing proper erosion remediation devices can help prevent these issues.	9/27/2017 10:49 AM
11	No	9/26/2017 3:02 PM
12	Use a lot of rock or spend the $'s to install the pre-fabricated kinds.	9/26/2017 2:24 PM
13	We have been installing fabric and stone in our maintenance operations	9/26/2017 1:42 PM
14	idenitfy soil types, grades & surface water velocity and design accordingly	9/26/2017 1:38 PM
15	By placing rock check dams more frequently through ditch channel to slow down the water flow.	9/26/2017 8:27 AM
16	We are considering trials with tied block products such as flexamat in some locations.	9/25/2017 3:54 PM

Q1 Respondent contact information.

Answered: 4 Skipped: 0

ANSWER CHOICES	RESPONSES	
Name	100.00%	4
Company	100.00%	4
Address	0.00%	0
Address 2	0.00%	0
City/Town	0.00%	0
State/Province	0.00%	0
ZIP/Postal Code	0.00%	0
Country	0.00%	0
Email Address	75.00%	3
Phone Number	100.00%	4

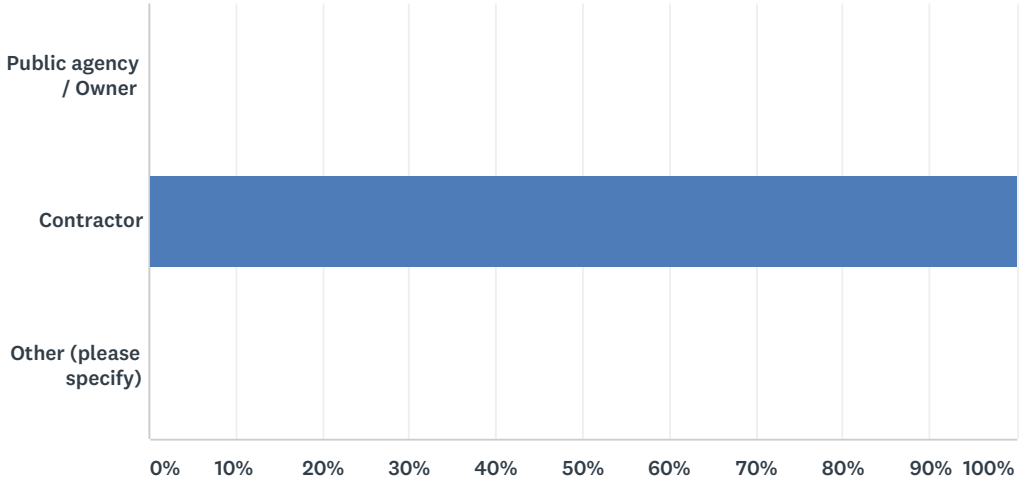
#	NAME	DATE
1	David Downs	10/2/2017 4:04 PM
2	David Newcomer	10/2/2017 3:56 PM
3	Adam Bean	10/2/2017 2:38 PM
4	Jon Pulcheon	10/2/2017 9:50 AM
#	COMPANY	DATE
1	George J. Igel & Co., Inc.	10/2/2017 4:04 PM
2	Newcomer Concrete	10/2/2017 3:56 PM
3	Kokosing	10/2/2017 2:38 PM
4	Trucco Construction	10/2/2017 9:50 AM
#	ADDRESS	DATE
	There are no responses.	
#	ADDRESS 2	DATE
	There are no responses.	
#	CITY/TOWN	DATE
	There are no responses.	
#	STATE/PROVINCE	DATE
	There are no responses.	
#	ZIP/POSTAL CODE	DATE
	There are no responses.	
#	COUNTRY	DATE
	There are no responses.	
#	EMAIL ADDRESS	DATE
1	david.downs@igelco.com	10/2/2017 4:04 PM

2	dadidn@newcomerconcrete.com	10/2/2017 3:56 PM
3	Jon.Pulcheon@TruccoConstruction.com	10/2/2017 9:50 AM

#	PHONE NUMBER	DATE
1	614-445-8421	10/2/2017 4:04 PM
2	614-792-1105	10/2/2017 3:56 PM
3	614-228-1029	10/2/2017 2:38 PM
4	614-915-7004	10/2/2017 9:50 AM

Q2 Which of the following best describes your organization?

Answered: 4 Skipped: 0



ANSWER CHOICES	RESPONSES	
Public agency / Owner	0.00%	0
Contractor	100.00%	4
Other (please specify)	0.00%	0
TOTAL		4

#	OTHER (PLEASE SPECIFY)	DATE
	There are no responses.	

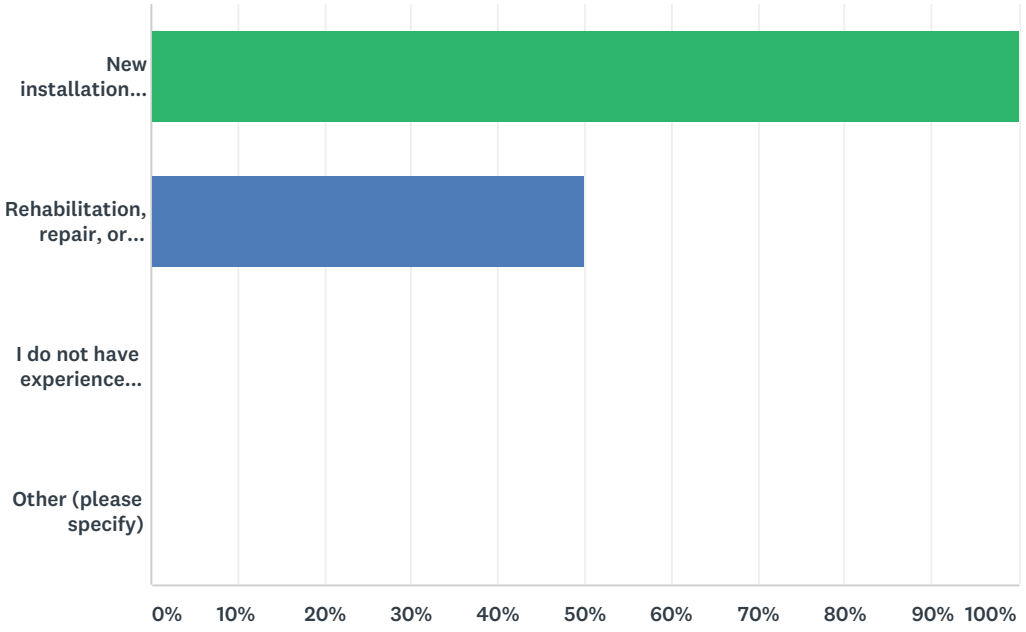
Q3 What is your role in your organization?

Answered: 4 Skipped: 0

#	RESPONSES	DATE
1	VP of Operations	10/2/2017 4:04 PM
2	Owner	10/2/2017 3:56 PM
3	Project Manager	10/2/2017 2:38 PM
4	Project Manager	10/2/2017 9:50 AM

Q4 Which of the following statements describe your experience constructing paved gutters...

Answered: 4 Skipped: 0

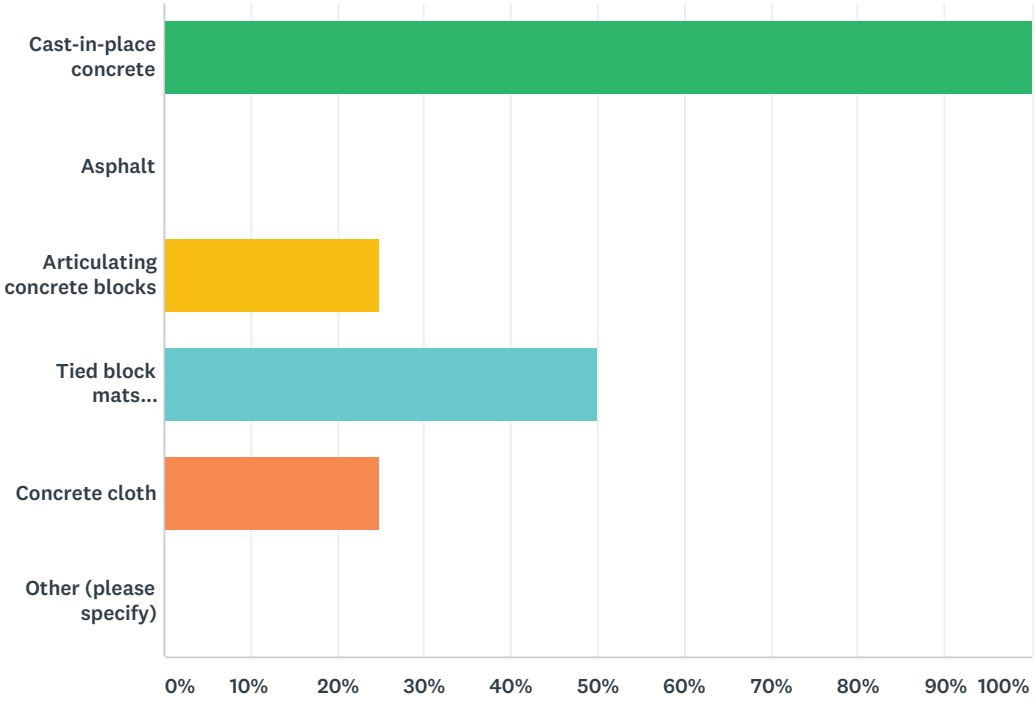


ANSWER CHOICES	RESPONSES	
New installation of concrete ditch lining used for roadside drainage.	100.00%	4
Rehabilitation, repair, or replacement of concrete ditch lining used for roadside drainage.	50.00%	2
I do not have experience constructing paved gutter systems.	0.00%	0
Other (please specify)	0.00%	0
Total Respondents: 4		

#	OTHER (PLEASE SPECIFY)	DATE
	There are no responses.	

Q5 What materials have you used in the construction of paved gutters?

Answered: 4 Skipped: 0

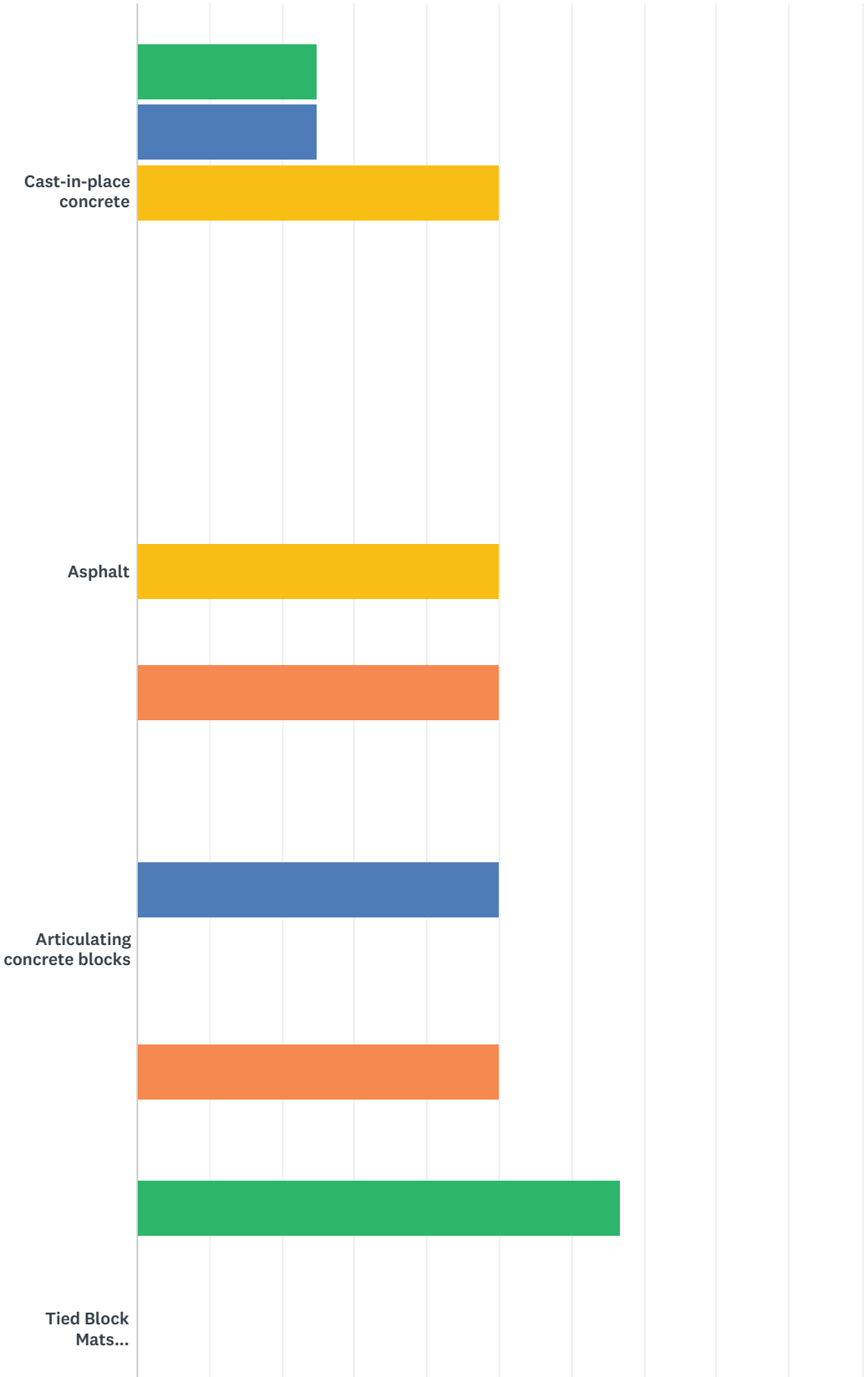


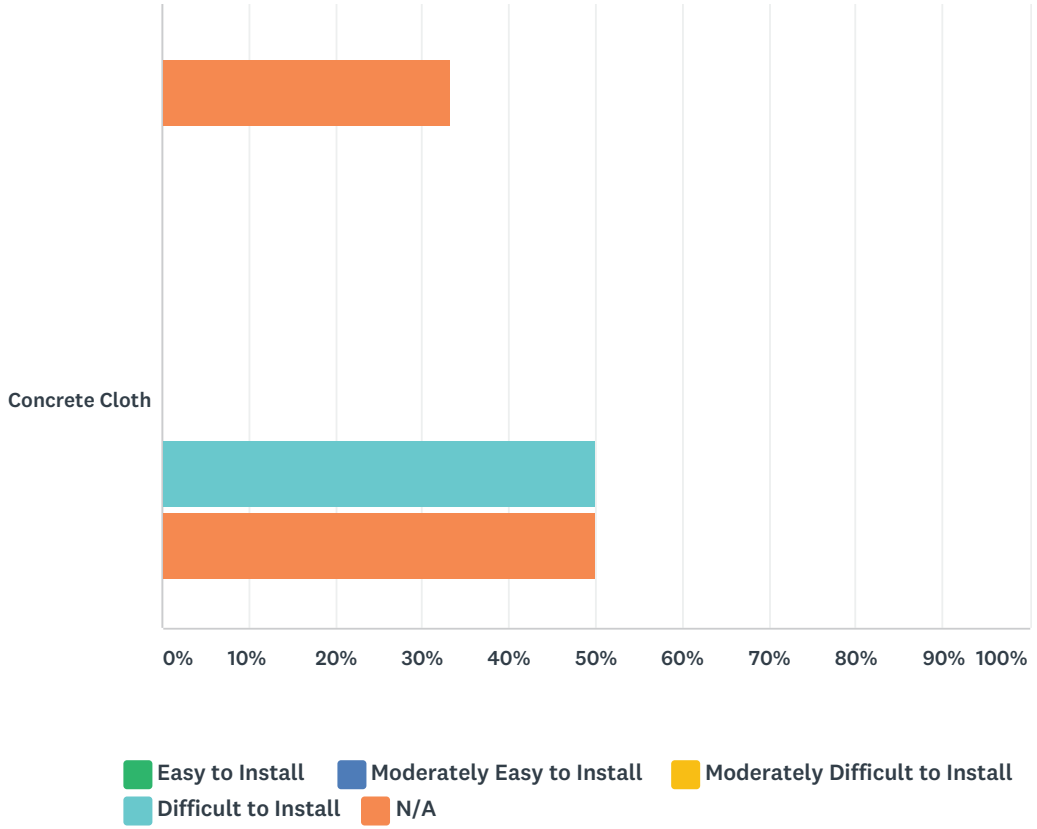
ANSWER CHOICES	RESPONSES	
Cast-in-place concrete	100.00%	4
Asphalt	0.00%	0
Articulating concrete blocks	25.00%	1
Tied block mats (Flex-a-mat)	50.00%	2
Concrete cloth	25.00%	1
Other (please specify)	0.00%	0
Total Respondents: 4		

#	OTHER (PLEASE SPECIFY)	DATE
	There are no responses.	

Q6 Please rate the materials you have used in constructing paved gutters according to ease of installation.

Answered: 4 Skipped: 0



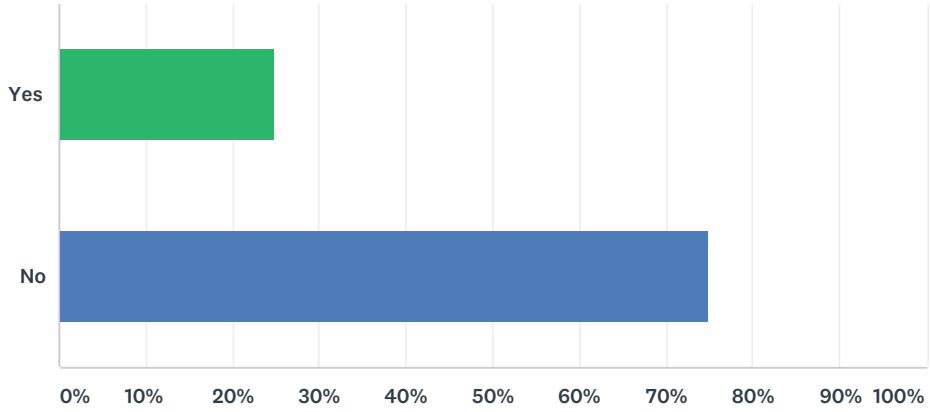


	EASY TO INSTALL	MODERATELY EASY TO INSTALL	MODERATELY DIFFICULT TO INSTALL	DIFFICULT TO INSTALL	N/A	TOTAL
Cast-in-place concrete	25.00% 1	25.00% 1	50.00% 2	0.00% 0	0.00% 0	4
Asphalt	0.00% 0	0.00% 0	50.00% 1	0.00% 0	50.00% 1	2
Articulating concrete blocks	0.00% 0	50.00% 1	0.00% 0	0.00% 0	50.00% 1	2
Tied Block Mats (Flex-a-mat)	66.67% 2	0.00% 0	0.00% 0	0.00% 0	33.33% 1	3
Concrete Cloth	0.00% 0	0.00% 0	0.00% 0	50.00% 1	50.00% 1	2

#	OTHER (PLEASE SPECIFY)	DATE
	There are no responses.	

Q7 For cast-in-place concrete paved gutters, have you used mix designs other than 4,000 psi compressive strength with air entrainment?

Answered: 4 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	25.00%	1
No	75.00%	3
TOTAL		4

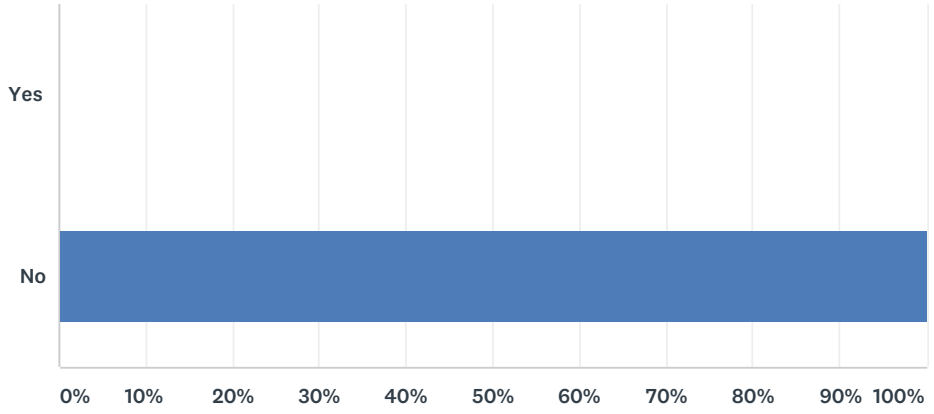
Q8 If your answer to the prior question was yes, please elaborate on the mix specifications and note any positive or negative experiences using the alternate concrete mix.

Answered: 1 Skipped: 3

#	RESPONSES	DATE
1	ODOT Class C	10/2/2017 3:57 PM

Q9 For cast-in-place concrete paved gutters, have you encountered specifications requiring fiber reinforcement in the mix design?

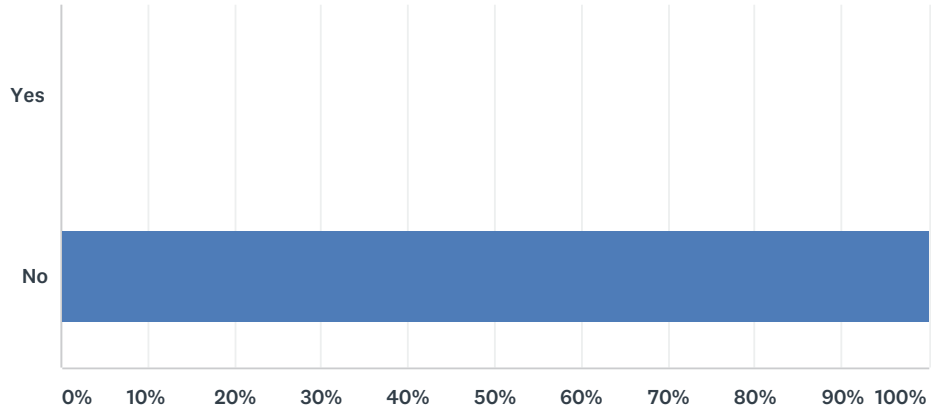
Answered: 4 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	0.00%	0
No	100.00%	4
TOTAL		4

Q10 For cast-in-place concrete paved gutters, have you encountered specifications requiring special admixtures to be incorporated in the mix design?

Answered: 4 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	0.00%	0
No	100.00%	4
TOTAL		4

Q11 If your answer to the prior question was yes, please elaborate on the required admixtures and note any positive or negative experiences using the admixtures.

Answered: 0 Skipped: 4

#	RESPONSES	DATE
	There are no responses.	

Q12 For cast-in-place concrete paved gutters, please describe your experience and process for installing the concrete, including any special equipment used for milling and slipforming.

Answered: 4 Skipped: 0

#	RESPONSES	DATE
1	Typically hand-formed, non-machined	10/2/2017 4:07 PM
2	Most of what we have been done has been hand formed not slipformed.	10/2/2017 3:58 PM
3	Typically formed and poured. If long sections and consistent width will slipform.	10/2/2017 2:40 PM
4	Paved gutters can be difficult to construct depending on there location. They are normally an expensive operation, requiring access to be constructed to get the equipment, materials and concrete mix to the site. Also, may involve the use of concrete pumps.	10/2/2017 9:55 AM

Q13 For non-concrete paved gutter materials, please describe your experience and process for installation. Note if any special equipment was utilized to facilitate installation.

Answered: 4 Skipped: 0

#	RESPONSES	DATE
1	Bobcat & Laborers. Nothing special.	10/2/2017 4:08 PM
2	N/A	10/2/2017 3:58 PM
3	Haven't used other materials.	10/2/2017 2:40 PM
4	Flex-a-mat concrete can be a viable alternative to concrete paved gutters. Smaller equipment, less preparation, easier installation. A mall excavator or skid steer may be utilized for the installation requiring a great deal less labor.	10/2/2017 9:57 AM

Q14 Have you identified solutions to reduce time and/or expense with ditch protection, with respect to labor, materials, equipment, means and/or methods? Please describe.

Answered: 4 Skipped: 0

#	RESPONSES	DATE
1	Use rock instead	10/2/2017 4:09 PM
2	No	10/2/2017 3:59 PM
3	Use standard shapes.	10/2/2017 2:41 PM
4	Yes	10/2/2017 9:59 AM

Q15 Do you have any other suggestions for rehabilitating existing paved gutters?

Answered: 4 Skipped: 0

#	RESPONSES	DATE
1	bust them up and use rock instead	10/2/2017 4:09 PM
2	No	10/2/2017 3:59 PM
3	no	10/2/2017 2:41 PM
4	No	10/2/2017 9:59 AM

Q16 Do you have any other suggestions for addressing channel erosion in existing roadside ditches?

Answered: 4 Skipped: 0

#	RESPONSES	DATE
1	no	10/2/2017 4:09 PM
2	No	10/2/2017 3:59 PM
3	no	10/2/2017 2:41 PM
4	No	10/2/2017 9:59 AM

APPENDIX C:

Construction Observation Reports

Construction Observation Report

5500 New Albany Road
Columbus, Ohio 43054

Phone: 614.775.4500
Fax: 614.775.4896

Project: 20170895
Date: 10/19/2017
Thursday

PROJECT NAME:

Evaluate Alternatives to Right of Way Drainage Control along Interstate

CONTRACTORS:

Contractor	Work Force	Equipment	Work Hours
ODOT	1 Foreman Aaron, 1 opreator, laborers	1 med sise backhoe, 3 dump trucks, 3 sevice trucks, 1 compressor, hand tools	08:00 - 16:00

SUMMARY OF WORK:

RPR Simmons obtained additional literature from the office, read over and reviewed ODOT Spec's, drawings and ODOT RFP 2018-11 to ensure I have a clear understanding and scope of what is requested by the Ohio Department of Transportation research Dept. for the evaluation of drainage control along interstates along Route 30 in Ashland County, Ohio.

Arrived on site early and spoke with ODOT foreman Aaron Martin and talked about work conditions and about adequate equipment to accomplish the task of removing and replacing the aged concrete gutter systems. Equipment being used currently was a smaller backhoe that made removal was not adequate size to include bucket size.

This slows removal production and with not being able to reach the dump trucks in one motion of removal, now it has to be picked up a second time and placed in dump trucks.

13:00 EMH&T Project Manager Holly Yaryan Hall arrived on site, then followed by Ashland County Manager Brad Mayes to review work in progress and review issues and any concerns for the evaluation observation.

All measurements will be done in the following reports, photos with explanations will be added to reports.

COMMUNICATION:

Jim Blackburn, Holly Yaryan Hall, Brad Mayes

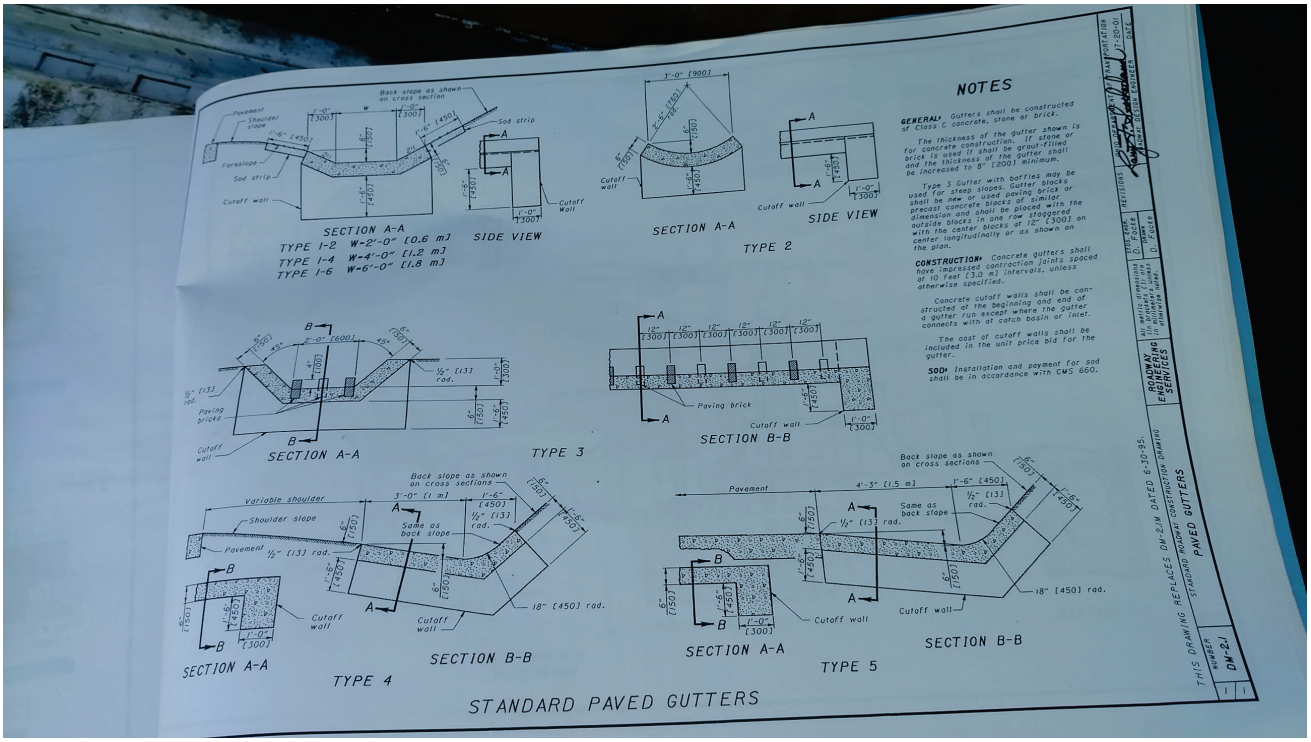
TRAFFIC CONTROL:

MOT not used

WEATHER:

Sky: Sunny **Temp:** 49-73 **Wind:** 5

RPR: Simmons, Robert **DATE:** 10/19/2017 **MILES:** 150.0000 **HOURS:** 5
SUPERVISOR: Blackburn, James **DATE:** 10/20/2017



Top right hand corner shows date of drawings being used by ODOT as 1-20-01

My ODOT drawings are dated 1-18-13

Current condition of concrete gutter system along Rt. 30 Ashland, Ohio.

Construction Observation Report

5500 New Albany Road
Columbus, Ohio 43054

Phone: 614.775.4500
Fax: 614.775.4896

Project: 20170895
Date: 10/23/2017
Monday

PROJECT NAME:

Evaluate Alternatives to Right of Way Drainage Control along Interstate

CONTRACTORS:

Contractor	Work Force	Equipment	Work Hours
ODOT	1 Foreman Aaron Martin, 1 opreator, 2 laborers	1 Kobelco SK 10 backhoe, 1 Kobelco 80 CS backhoe, 2 service trucks, 1 compressor, hand tools	08:30 - 10:40

SUMMARY OF WORK:

07:30 RPR Simmons arrived on site with no ODOT works on site yet. I measured scope of work to be completed for the evaluation (remove and replace 118.5 Lf. of concrete gutter) to be calculated for the man hours turned into Kelly for the cost and time efficiency as part of the study.

08:15 1 service truck arrived with 2 personnel, 08:30 foreman Aaron with 1 laborer. Total 4 men. Crew began the removal of forms for the concrete work placed last Friday (this work was not observed), then began forming additional adjacent sections. One worker said the the keys to backhoes were at another post for removal of the deteriorated concrete gutter removal. I observed them looking at other issues not associated to this work. The Foreman said they were worried about the forecasted rain and departed at 10:40. During the time that laborers were on site no one made an attempt to retrieve the keys.

13:15 Communicated with EMH&T Project Manager Holly Yaryan Hall on the days observation.

13:00 I stayed until moderate rain began to determine actual work time lost.

COMMUNICATION:

Holly Yaryan Hall

TRAFFIC CONTROL:

N/A

WEATHER:

Sky: Rain **Temp:** 56-65 **Wind:** 10 **Comments:** Very light misty rain 11:45, Moderate rain 13:00

RPR: Simmons, Robert **DATE:** 10/23/2017 **MILES:** 150.0000 **HOURS:** 7
SUPERVISOR: Anderson, Amber **DATE:** 10/25/2017

Concrete gutter system work done on 20 October not observed by RPR

Concrete gutter system work done on 20 October not observed by RPR

Construction Observation Report

5500 New Albany Road
Columbus, Ohio 43054

Phone: 614.775.4500
Fax: 614.775.4896

Project: 20170895
Date: 10/27/2017
Friday

PROJECT NAME:

Evaluate Alternatives to Right of Way Drainage Control along Interstate

CONTRACTORS:

Contractor	Work Force	Equipment	Work Hours
ODOT	1 Foreman Aaron Martin, 2 operator, 3 laborers	1 Kobelco SK 10 backhoe, 1 Kobelco 80 CS backhoe, 2 service trucks, 1 compressor, hand tools	07:30 - 14:45

SUMMARY OF WORK:

RPR Simmons observed the ODOT crew form up the concrete drainage gutter along Interstate 30, and pour the required concrete according to the required spec. During observation the crew a couple of times forgot to wear proper eye, ear and breathing protection during saw cutting. The crew foreman was very knowledgeable in the proper techniques in forming and planning the work, however the crew as a whole is not experienced and work taking more time than needed. In my opinion in the most cost effective way for the ODOT organization is to hire a subcontractor to do the concrete work more efficiently in order to save the State money that could be used for better equipment and training.

Foreman did communicate his access to the most recent specifications and drawings was a big issue within the department and needed updated. He also conveyed that the County was under equipped with numerous equipment being spread thin, which delays work necessary to meet the demands of the workload within the county.

COMMUNICATION:

Holly Yaryan Hall

TRAFFIC CONTROL:

MOT not used

WEATHER:

Sky: Sunny **Temp:** 55-68 **Wind:** 14

RPR: Simmons, Robert **DATE:** 10/27/2017 **MILES:** 150.0000 **HOURS:** 8
SUPERVISOR: Anderson, Amber **DATE:** 10/30/2017

Foreman did a great job in planning and executing the work.

Placement of concrete was done by use of a backhoe which in this location worked fine. Workers in background did not have adequate safety PPE (Personnel Protective Equipment.)

APPENDIX D:

Ashland County U.S. Route 30 Cost Data

TMS WORK ORDER NUMBER	
County	Ashland
Route	30 / 60
Mile Marker From	
Mile Marker To	
Estimate completed by:	Mayes

Project Description: US30 Gutter repair / replace @ SR60

MATERIALS

MATERIAL		UNIT	QUANTITY	UNIT COST	TOTAL COST
# 43030550 REBAR, #5, 5/8", EPOXY COATED	43030550	FT	900	$1.08	$972.00
# 42010412 LIMESTONE, #411	42010412	TN	3	$13.70	$41.10
# 42010157 LIMESTONE, #57	42010157	TN	49	$16.70	$818.30
# 42020361 CONCRETE QCI	42020361	CU.YDS	9.5	$150.00	$1,425.00
# 52030143 PLYWOOD, 3/4"X4'X8'	52030143	EA	2	$24.99	$49.98
# 52010602 LUMBER, PINE 2"X6"X12"	52010602	EA	15	$7.19	$107.85
# 42020435 CONCRETE, CLASS C	42020435	CY	16.5	$150.08	$2,476.32
# 42010505 LIMESTONE, #2	42010505	TN	2	$16.77	$33.54
# 42011105 CALCIUM FLAKES 50LB BAG	42011105	BG	2	$13.69	$27.38
# 42040100 EPOXY	42040100	EA	2	$16.00	$32.00
				Total Materials	$5,983.47

LABOR - Hours

NAME	QUANTITY	UNIT COST	TOTAL COST
HIGHWAY TECH 1	36.5	$30.75	$1,122.38
HIGHWAY TECH 2	262.5	$35.01	$9,190.13
HIGHWAY TECH 3	85.5	$39.31	$3,361.01
		Total Labor	$13,673.51

EQUIPMENT

EQUIPMENT (select under equip type - to right)	SELECT HERE Eqp. Type	UNIT	QUANTITY	UNIT COST	TOTAL COST
PICKUP, 3/4 TON	222	mi	437	$0.78	$340.86
PICKUP, 1/2 TON	221	mi	48	$0.64	$30.72
DUMP TRUCK, 25000-35000GVW	254	mi	522	$3.79	$1,978.38
COMPRESSOR OVER 125CFM	372	hr	8	$32.23	$257.84
EXCAVATOR, LIGHT	470	hr	36	$39.11	$1,407.96
STAKE, 1 1/2 & OVER, STANDARD	233	mi	221	$2.59	$572.39
EXCAVATOR, HEAVY	471	hr	28	$49.95	$1,398.60
				Total Equipment	$5,986.75

Pertinent planning information

MILES FROM GARAGE TO JOB	
ESTIMATED DAYS TO COMPLETE	
DETOUR REQUIRED?	
# of Structures or Lane Miles impacted by work	6.20

Total Labor	$13,674
Total Equipment	$5,987
Total Materials	$5,983

EIMS work order:

County	Ashland
Route	30 / 60
SLM from	
SLM to	

TOTAL PROJECT COST $25,644

Project Cost per Lane Mile (structure) **4136.084677**

Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
Ashland	8728103	10/19/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-007 Culvert or Storm Spot Repair	Sq. Ft.

MANAGER NOTES

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1		8	ASD	30	W	Outside	6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT		EMPLOYEE	RG	OT
1	MARTIN AARON D ✓	8		6	SPRENG JEFFREY ✓	7.5	
2	HEFFELFINGER MICHAEL ✓	8		7	REISINGER MELVIN M ✓	8	
3	TIM BUTDORFF ✓	8		8	RILEY SCOTT ✓	8	
4	ROGERS SHAWN E ✓	8		9			
5	STARCHER CHRIS ✓	8		10			

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours
1	222-1381 T3518		8	77719	77740	21
2	222-1503 T3778		8	32636	32686	50
3	254-4506 T3557		8	151577	151612	35
4	254-5846 T3910		8	64885	64922	37
5	254-5666 T3629		8	86425	86468	43
6	470-0074		8			
7	221-1502 T3779		8	38910	38958	48
8	372-0249		8			
9						
10						
11						

Other Costs

Cost Type	Costs	Note

Material

	Material Master Code	Admin Unit	Quantity	UM
1	43-03-0550 REBAR, #5, 5/8", EPOXY COATED	ft	400	ft
2				
3				
4				
5				

Accomplishment	Quantity	UM	Comments
		Sq. Ft.	

CREW LEADER:	AARON MARTIN	SIGNATURE:	

Copy

Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
ASH	8728103 ✓	10/20/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-006B Drainage Structures Replacement ✓	

MANAGER NOTES

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1			ASH	30			6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT
1	MARTIN AARON D ✓	4.5 ✓	
2	BUTTDORF TIM ✓	4-8 ✓	"
3	HEFFELFINGER MICHAEL ✓	8 ✓	
4	REISINGER MELVIN M ✓	8 ✓	
5	RILEY SCOTT ✓	8 ✓	

	EMPLOYEE	RG	OT
6	SPRENG JEFFREY ✓	4-8 ✓	
7	STARCHER CHRIS ✓	8 ✓	
8	STITZLEIN BRUCE ✓	8 ✓	
9			
10			

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours
1	222-0694 T3819 ✓		8 ✓	191711	191733	22 ✓
2	222-1503 T3778 ✓		8 ✓	32686	32712	26 ✓
3	222-1381 T3518 ✓		8 ✓	77740	77764	24 ✓
4	254-5666 T3629 ✓		8 ✓	86468	86528	60 ✓
5	254-5846 T3910 ✓		8 ✓	64922	64977	55 ✓
6	2221502 - T3-779 ✓		8 ✓	38958	38986	28 ✓
7						
8						
9						
10						
11						

Other Costs

Cost Type	Costs	Note

Material

	Material Master Code	Admin Unit	Quantity	UM
1	42020361 - Concrete (CC) ✓		5 ✓	Cu. Yds
2	411 - 42-01-[illegible] 0412 ✓		3 ✓	tons
3	593 - 42-01-0159 ✓		12 ✓	ton
4				
5				

Accomplishment	Quantity	UM	Comments
	225	Sq Ft	

CREW LEADER: Aaron Martin

SIGNATURE: Aaron Martin

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Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
Ashland	8728103	10/23/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-007 Culvert or Storm Spot Repair	Sq. Ft.

MANAGER NOTES	removed old concrete,striped form, and made forms

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1		8	ASD	30	W	Outside	6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT		EMPLOYEE	RG	OT
1	MARTIN AARON D	8		6			
2	STARCHER CHRIS	8		7			
3	REISINGER MELVIN M	8		8			
4	RILEY SCOTT	8		9			
5				10			

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours
1	222-1381 T3518		8	77764	77794	30
2	222-1503 T3778					
3	254-4506 T3557					
4	254-5846 T3910					
5	254-5666 T3629					
6	470-0074					
7	221-1502 T3779					
8	372-0249 Air Comp					
9	233-0237 T3630		8	126032	126051	19
10						
11						

Other Costs

Cost Type	Costs	Note

Material

	Material Master Code	Admin Unit	Quantity	UM
1	43-03-0550 REBAR, #5, 5/8", EPOXY COATED		none	
2	42-01-0157 LIMESTONE, #57	tons	5	tons
3	52-03-0143 PLYWOOD, 3/4" X 4' X 8'	each	2	each
4	52-01-0602 LUMBER, PINE 2"x6"x12"	each	15	each
5				

Accomplishment	Quantity	UM	Comments
		Sq. Ft.	

CREW LEADER:	AARON MARTIN	SIGNATURE:	Aaron J Martin

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Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
Ashland	8728103	10/26/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-007 Culvert or Storm Spot Repair	Sq. Ft.

MANAGER NOTES

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1		8	ASD	30	W	Outside	6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT		EMPLOYEE	RG	OT
1				6			
2	HEFFELFINGER MICHAEL	4		7	REISINGER MELVIN M	4	
3	TIM BUTDORFF	4		8	RILEY SCOTT	4	
4	EAGLE SCOTT A	4		9			
5	STARCHER CHRIS	4		10			

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours	Other Costs: Cost Type	Costs	Note
1	222-1381 T3518		4	77794	77812	18			
2	222-1503 T3778		4	32712	32840	28			
3	254-4506 T3557								
4	254-4537 T3534		4	138739	138772	33			
5	254-5666 T3629								
6	470-0074								
7	221-1502 T3779								
8	372-0249								
9	233-0237 T3630		4	126051	126125	74			
10									
11									

Material

	Material Master Code	Admin Unit	Quantity	UM
1	42-01-0157 P-VILLES 57 LIMESTONE	tons	17	tons
2				
3				
4				
5				

Accomplishment	Quantity	UM	Comments
		Sq. Ft.	

CREW LEADER:	AARON MARTIN	SIGNATURE:	

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Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
Ashland	8728103	10/27/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-007 Culvert or Storm Spot Repair	Sq. Ft.

MANAGER NOTES

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1		4	ASD	30	W	Outside	6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT		EMPLOYEE	RG	OT
1	MARTIN AARON D			6	SPRENG JEFFREY	7	
2	HEFFELFINGER MICHAEL			7	REISINGER MELVIN M	8	
3	TIM BUTDORFF	8		8			
4	EAGLE SCOTT A	8		9			
5	STARCHER CHRIS	8		10	STITZLEIN BRUCE	8	

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours	Other Costs: Cost Type	Costs	Note
1	222-1381 T3518		8	77712	77832	20			
2	222-1503 T3778								
3	254-4506 T3557		8	151776	151835	59			
4	254-4537 T3534		8	138772	138791	19			
5	254-5666 T3629								
6	470-0074								
7	221-1502 T3779								
8	372-0249								
9	233-0237 T3630		8	126125	126144	21			
10	471-0088		8						
11									

Material

	Material Master Code	Admin Unit	Quantity	UM
1	42-01-0157 LIMESTONE, #57	tons	7	tons
2	42-02-0435 CONCRETE, CLASS C	yards	4	yards
3				
4				
5				

Accomplishment	Quantity	UM	Comments
	120	Sq. Ft.	

CREW LEADER:	AARON MARTIN	SIGNATURE:	

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Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
Ashland	8728103	10/30/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-007 Culvert or Storm Spot Repair	Sq. Ft.

MANAGER NOTES

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1		4	ASD	30	W	Outside	6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT
1	MARTIN AARON D	8	
2	HEFFELFINGER MICHAEL	8	
3	RILEY SCOTT	8	
4	MARKS RYAN P	8	
5	STARCHER CHRIS	8	

	EMPLOYEE	RG	OT
6	REISINGER MELVIN M	8	
7			
8			
9			
10			

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours
1	222-1381 T3518		8	77832	77852	20
2	222-1503 T3778					
3	254-5870 T3787		8	62222	62314	92
4	254-5938 T3935		8	46460	46527	67
5	254-5666 T3629					
6	470-0074		8			
7	471-0088		8			
8	372-0249					
9	233-0237 T3630		8	126144	126163	19
10						
11						

Other Costs

Cost Type	Costs	Note

Material

	Material Master Code	Admin Unit	Quantity	UM
1	43-03-0550 REBAR, #5, 5/8", EPOXY COATED	ft	240	ft
2	42-01-0505 LIMESTONE, #2	tons	2	tons
3	42-01-0157 LIMESTONE, #57	tons	4	tons
4	42-02-0435 CONCRETE, CLASS C	yards	6	yards
5	57-06-0211	Each	1	Each

Accomplishment	Quantity	UM	Comments
	180	Sq. Ft.	

CREW LEADER:	AARON MARTIN	SIGNATURE:	

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Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
Ashland	8728103	10/31/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-007 Culvert or Storm Spot Repair	Sq. Ft.

MANAGER NOTES

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1		4	ASD	30	W	Outside	6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT		EMPLOYEE	RG	OT
1	MARTIN AARON D			6	REISINGER MELVIN M	8	0.5
2	HEFFELFINGER MICHAEL	8	0.5	7			
3	RILEY SCOTT	8	0.5	8			
4	STITZLEIN BRUCE	8	0.5	9			
5	STARCHER CHRIS	8	0.5	10			

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours
1	222-1381 T3518		8	77852	77870	18
2	222-1503 T3778		8	32933	32967	34
3	254-5870 T3787					
4	254-4537 T3534		8	138791	138812	22
5	254-5666 T3629					
6	470-0074		8			
7	471-0088		8			
8	372-0249					
9	233-0237 T3630		8	126163	126181	18
10						
11						

Other Costs

Cost Type	Costs	Note

Material

	Material Master Code	Admin Unit	Quantity	UM
1	43-03-0550 REBAR, #5, 5/8", EPOXY COATED	ft	260	ft
2	42-01-1105 CALCIUM CHLORIDE FLAKES (50 LB BAG)	each	1	each
3	42-01-0157 LIMESTONE, #57	tons	4	tons
4	42-02-0435 CONCRETE, CLASS C	yards	6.5	yards
5				

Accomplishment	Quantity	UM	Comments
	180	Sq. Ft.	

CREW LEADER:	AARON MARTIN	SIGNATURE:	

Copy

Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
Ashland	8728103	11/1/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-007 Culvert or Storm Spot Repair	Sq. Ft.

MANAGER NOTES

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1		4	ASD	30	W	Outside	6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT		EMPLOYEE	RG	OT
1	MARTIN AARON D	1		6	REISINGER MELVIN M	4	
2	HEFFELFINGER MICHAEL	4		7			
3	RILEY SCOTT	4		8			
4	STITZLEIN BRUCE	4		9			
5	STARCHER CHRIS	4		10			

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours	Other Costs: Cost Type	Costs	Note
1	222-1381 T3518		4	77870	77910	40			
2	222-1503 T3778								
3	254-5870 T3787								
4	254-4537 T3534								
5	254-5666 T3629								
6	470-0074		4						
7	471-0088		4						
8	372-0249								
9	233-0237 T3630		4	126181	126211	30			
10									
11									

Material

	Material Master Code	Admin Unit	Quantity	UM
1	43-03-0550 REBAR, #5, 5/8", EPOXY COATED			
2	42-01-1105 CALCIUM CHLORIDE FLAKES (50 LB BAG)			
3	42-01-0157 LIMESTONE, #57			
4	42-02-0435 CONCRETE, CLASS C			
5				

	Accomplishment	Quantity	UM	Comments
			Sq. Ft.	

CREW LEADER:	AARON MARTIN	SIGNATURE:	

Copy

Day Card Work Sheet

COUNTY / LOCATION / COST CENTER	WORK ORDER #	WORK DATE
Ashland	8728103	11/2/2017

PROJECT	ACTIVITY CODE and DESCRIPTION	UNIT OF MEASURE
	M611-007 Culvert or Storm Spot Repair	Sq. Ft.

MANAGER NOTES

Location

	INV. Item	Portion	County	Route	Direction	Lane	Begin	End
1		4	ASD	30	W	Outside	6.08	6.17
2								
3								
4								
5								
6								

Employee

	EMPLOYEE	RG	OT		EMPLOYEE	RG	OT
1	MARTIN AARON D	8		6	REISINGER MELVIN M	8	
2	HEFFELFINGER MICHAEL	8		7			
3	RILEY SCOTT	8		8			
4	STITZLEIN BRUCE	8		9			
5	STARCHER CHRIS	8		10			

Equipment

	Equipment #	Lic #	Hrs on job	Begin	End	Miles/Hours
1	222-1381 T3518		8	77938	77956	18
2	222-1503 T3778		8	33000	33022	22
3	254-5870 T3787					
4	254-4537 T3534					
5	254-5666 T3629					
6	470-0074		8			
7	471-0088		8			
8	372-0249					
9	233-0237 T3630		8	126239	126279	40
10	222-0702 T3801		8	127278	127596	18
11						

Other Costs

Cost Type	Costs	Note

Material

	Material Master Code	Admin Unit	Quantity	UM
1	43-03-0550 REBAR, #5, 5/8", EPOXY COATED			
2	42-01-1105 CALCIUM CHLORIDE FLAKES (50 LB BAG)	bag	1	bag
3	42-01-0157 LIMESTONE, #57			
4	42-02-0361 QCI CONCRETE	yards	4.5	yards
5	42-04-0100 EPOXY	each	2	each

Accomplishment	Quantity	UM	Comments
	120	Sq. Ft.	

CREW LEADER:	AARON MARTIN	SIGNATURE:	

APPENDIX E:

Historical Bid Item Data

..	Co...	Project Type
07	WAR	BRIDGE REPAIR
08	MAR	BRIDGE REPLACEMENT (1 BRIDGE)
09	AUG	CULVERT REPLACEMENT
10	ADA	INTERCHANGE

..
16
10

Count	Min Bid Price	Avg Award Price
6	$5.00	$21.08

Max Bid Price	Avg Bid Price
$46.00	$21.04

Enter an item

Dist	County	PID	Spec Year	Letting	Item	Qty	Units	Proposal Line #	Min Bid
09	PIK	95402	13	1/9/2014	202E32700	52	SY	0003	5
07	MIA	88727	13	10/2/2014	202E32700	36	SY	0003	5
12	CUY	98965	13	1/28/2016	202E32700	88	SY	0003	9
10	HOC	103543	16	3/30/2017	202E32700	35	SY	0004	10
08	WAR	93964	16	4/6/2017	202E32700	48	SY	0006	5
12	CUY	99998	16	4/27/2017	202E32700	153	SY	0002	29.35

code below and press "Search"

202e32700

Clear: All

Project #

168032

168033

168034

170001

Enter a supplemental description below and press "Search"

gutter

Max Bid	Average Bid	Award Bid	# of Bidders	Item Description
20	12.5	5	8	GUTTER REMOVED
45	17.231	10	10	GUTTER REMOVED
25	17.66666	22	6	GUTTER REMOVED
30	18.16666	20	6	GUTTER REMOVED
40	22.74222	23.48	9	GUTTER REMOVED
46	37.95	46	3	GUTTER REMOVED

Project Type	Project #	Contract ID	County, Route, and Section	Plan Link	Work Type
BRIDGE REPAIR	140026	PIK95402	PIK-CR85-0.91	#\\itcpl100\plar	BH
BRIDGE REPLACEMENT (1 BRIDGE)	140495	MIA88727	MIA-SR 41-2.31	#\\itcpl100\plar	BR
CULVERT REPLACEMENT	160048	CUY98965	CUY-IR 71-3.01	#\\itcpl100\plar	DRNG
INTERSECTION	170169	HOC103543	HOC-US 33-11.70	#\\itcpl100\plar	GEN
INTERCHANGE	170116	WAR93964	WAR-IR 71-03.62	#\\itcpl100\plar	GEN
CULVERT REPLACEMENT	170283	D1299998	D12 CU FY2017	#\\itcpl100\plar	DRNG

..	Co...	Project Type
08	MAR	BRIDGE REPAIR
09	AUG	CULVERT REPLACEMENT
12	ADA	MAJOR WIDENING
01	ALL	MISCELLANEOUS

..
16
10

Count	Min Bid Price	Avg Award Price
5	$40.00	$99.19

Max Bid Price	Avg Bid Price
$292.91	$104.80

Enter an item

Dist	County	PID	Spec Year	Letting	Item	Qty	Units	Proposal Line #	Min Bid
09	PIK	95402	13	1/9/2014	601E38000	90	FT	0016	46
08	BUT	75686	13	2/6/2014	601E38001	70	FT	0031	71.55
08	HAM	82286	13	5/22/2014	601E38001	52	FT	0395	40
12	CUY	92929	13	7/2/2015	601E38001	90	FT	0007	95
12	CUY	99998	16	4/27/2017	601E38000	230	FT	0007	59.91

code below and press "Search"

601E3800

Clear: All

Project #

168034

170001

170002

170003

Enter a supplemental description below and press "Search"

gutter

Max Bid	Average Bid	Award Bid	# of Bidders	Item Description
125	72.0625	71.5	8	PAVED GUTTER, TYPE 1-4
155.45	109.22833	155.45	6	PAVED GUTTER, TYPE 1-4, AS PER PLAN
95	73.686	85.98	5	PAVED GUTTER, TYPE 1-4, AS PER PLAN
292.91	193.955	95	2	PAVED GUTTER, TYPE 1-4, AS PER PLAN
88	75.07	88	3	PAVED GUTTER, TYPE 1-4

Project Type	Project #	Contract ID	County, Route, and Section	Plan Link	Work Type
BRIDGE REPAIR	140026	PIK95402	PIK-CR85-0.91	#\\itcpl100\plar	BH
MISCELLANEOUS	140067	BUT75686	BUT-177-10.48	#\\itcpl100\plar	GEN
MAJOR WIDENING	140267	HAM82286	HAM-75-6.78	#\\itcpl100\plar	GEN
SLIDE REPAIR	150399	CUY92929	CUY-IR 480-15.60	#\\itcpl100\plar	ERTH
CULVERT REPLACEMENT	170283	D1299998	D12 CU FY2017	#\\itcpl100\plar	DRNG

APPENDIX F:

Alternative Cost Analysis

Scenario	Labor**	Equipment***	Materials****	Total	Total Savings	Cost Per SF	Savings Per SF	Cost Per LF	Savings Per LF	Savings (%)
ASD-30 Cost Data*	$ 13,674	$ 5,987	$ 5,983	$ 25,644		$ 31.08		$ 216.41		
Alternative 1: Skid Steer Loader	$ 13,674	$ 5,295	$ 5,983	$ 24,952	$ 692	$ 30.24	$ 0.84	$ 210.57	$ 5.84	2.7%
Alternative 2: Slipform Machine	$ 10,256	$ 8,548	$ 4,822	$ 23,626	$ 2,018	$ 28.64	$ 2.45	$ 199.38	$ 17.03	7.9%
Alternative 3: All of the Above	$ 10,256	$ 7,856	$ 4,822	$ 22,934	$ 2,710	$ 27.80	$ 3.28	$ 193.54	$ 22.87	10.6%

Notes

*Actual cost data from the ASD-30 project was used as the point of comparison. It was assumed the light excavator was primarily used to demo/remove concrete, and the heavy excavator bucket was used to pour concrete. 225 square feet - 118.5 linear feet per RPR Simmons, plus additional storm sewer outlet pads.

**Labor was assumed to be reduced by 25% for Alternatives 2 and 3. For ASD-30, using a slip-form machine would have required some additional labor on the front end to prepare the subgrade and check grades, and then reduced labor on the back end.

***Equipment costs for Alternatives 1 and 3 were reduced by shifting half of the light excavator hours to the skid steer loader (hoe ram). For Alternatives 2 and 3, the heavy excavator was replaced by the slipform machine and skid steer loader.

****Materials were assumed to remain the same for Alternative 1. For Alternatives 2 and 3, it was assumed the plywood and other form materials could be eliminated.

TMS WORK ORDER NUMBER	
County	Ashland
Route	30 / 60
Mile Marker From	
Mile Marker To	
Estimate completed by:	Mayes

Project Description

US30 Gutter repair / replace @ SR60, Alternative 1: Skid Steer Loader (Replace half of light excavator hours with skid steer loader. Eliminate compressor/jackhammer.)

MATERIALS

MATERIAL		UNIT	QUANTITY	UNIT COST	TOTAL COST
# 43030550 REBAR, #5, 5/8", EPOXY COATED	43030550	FT	900	$1.08	$972.00
# 42010412 LIMESTONE, #411	42010412	TN	3	$13.70	$41.10
# 42010157 LIMESTONE, #57	42010157	TN	49	$16.70	$818.30
# 42020361 CONCRETE QCI	42020361	CU.YDS	9.5	$150.00	$1,425.00
# 52030143 PLYWOOD, 3/4"X4'X8'	52030143	EA	2	$24.99	$49.98
# 52010602 LUMBER, PINE 2"X6"X12"	52010602	EA	15	$7.19	$107.85
# 42020435 CONCRETE, CLASS C	42020435	CY	16.5	$150.08	$2,476.32
# 42010505 LIMESTONE, #2	42010505	TN	2	$16.77	$33.54
# 42011105 CALCIUM FLAKES 50LB BAG	42011105	BG	2	$13.69	$27.38
# 42040100 EPOXY	42040100	EA	2	$16.00	$32.00
				Total Materials	$5,983.47

LABOR - Hours

NAME	QUANTITY	UNIT COST	TOTAL COST
HIGHWAY TECH 1	36.5	$30.75	$1,122.38
HIGHWAY TECH 2	262.5	$35.01	$9,190.13
HIGHWAY TECH 3	85.5	$39.31	$3,361.01
		Total Labor	$13,673.51

EQUIPMENT

SELECT HERE

EQUIPMENT (select under equip type - to right)	Eqp. Type	UNIT	QUANTITY	UNIT COST	TOTAL COST
PICKUP, 3/4 TON	222	mi	437	$0.78	$340.86
PICKUP, 1/2 TON	221	mi	48	$0.64	$30.72
DUMP TRUCK, 25000-35000GVW	254	mi	522	$3.79	$1,978.38
COMPRESSOR OVER 125CFM	372	hr		$32.23	
EXCAVATOR, LIGHT	470	hr	18	$39.11	$703.98
STAKE, 1 1/2 & OVER, STANDARD	233	mi	221	$2.59	$572.39
EXCAVATOR, HEAVY	471	hr	28	$49.95	$1,398.60
LOADER, SKID STEER	591	hr	18	$15.00	$270.00
				Total Equipment	$5,294.93

Pertinent planning information

MILES FROM GARAGE TO JOB	
ESTIMATED DAYS TO COMPLETE	
DETOUR REQUIRED?	
# of Structures or Lane Miles impacted by work	6.20

Total Labor	$13,674
Total Equipment	$5,295
Total Materials	$5,983

EIMS work order

County	Ashland
Route	30 / 60
SLM from	
SLM to	

TOTAL PROJECT COST $24,952

Project Cost per Lane Mile (structure) **4024.500806**

TMS WORK ORDER NUMBER	
County	Ashland
Route	30 / 60
Mile Marker From	
Mile Marker To	
Estimate completed by:	Mayes

Project Description

US30 Gutter repair / replace @ SR60, Alternative 2: Slipform Machine (Reduce labor by 25%. Eliminate heavy excavator and form materials. One day of slipform machine plus skid steer loader.)

MATERIALS

MATERIAL		UNIT	QUANTITY	UNIT COST	TOTAL COST
# 43030550 REBAR, #5, 5/8", EPOXY COATED	43030550	FT		$1.08	
# 42010412 LIMESTONE, #411	42010412	TN	3	$13.70	$41.10
# 42010157 LIMESTONE, #57	42010157	TN	49	$16.70	$818.30
# 42020361 CONCRETE QCI	42020361	CU.YDS	9.5	$150.00	$1,425.00
# 52030143 PLYWOOD, 3/4"X4'X8'	52030143	EA		$24.99	
# 52010602 LUMBER, PINE 2"X6"X12"	52010602	EA		$7.19	
# 42020435 CONCRETE, CLASS C	42020435	CY	16.5	$150.08	$2,476.32
# 42010505 LIMESTONE, #2	42010505	TN	2	$16.77	$33.54
# 42011105 CALCIUM FLAKES 50LB BAG	42011105	BG	2	$13.69	$27.38
# 42040100 EPOXY	42040100	EA		$16.00	
				Total Materials	$4,821.64

LABOR - Hours

NAME	QUANTITY	UNIT COST	TOTAL COST
HIGHWAY TECH 1	32	$30.75	$984.00
HIGHWAY TECH 2	184	$35.01	$6,441.84
HIGHWAY TECH 3	72	$39.31	$2,830.32
		Total Labor	$10,256.16

EQUIPMENT

SELECT HERE

EQUIPMENT (select under equip type - to right)	Eqp. Type	UNIT	QUANTITY	UNIT COST	TOTAL COST
PICKUP, 3/4 TON	222	mi	437	$0.78	$340.86
PICKUP, 1/2 TON	221	mi	48	$0.64	$30.72
DUMP TRUCK, 25000-35000GVW	254	mi	522	$3.79	$1,978.38
COMPRESSOR OVER 125CFM	372	hr	8	$32.23	$257.84
EXCAVATOR, LIGHT	470	hr	36	$39.11	$1,407.96
STAKE, 1 1/2 & OVER, STANDARD	233	mi	221	$2.59	$572.39
EXCAVATOR, HEAVY	471	hr		$49.95	
LOADER, SKID STEER	591	hr	8	$15.00	$120.00
SLIPFORM MACHINE	ASD	hr	8	$480.00	$3,840.00
				Total Equipment	$8,548.15

Pertinent planning information

MILES FROM GARAGE TO JOB	
ESTIMATED DAYS TO COMPLETE	
DETOUR REQUIRED?	
# of Structures or Lane Miles impacted by work	6.20

Total Labor	$10,256
Total Equipment	$8,548
Total Materials	$4,822

EIMS work order

County	Ashland
Route	30 / 60
SLM from	
SLM to	

TOTAL PROJECT COST $23,626

Project Cost per Lane Mile (structure) 3810.637097

TMS WORK ORDER NUMBER	
County	Ashland
Route	30 / 60
Mile Marker From	
Mile Marker To	
Estimate completed by:	Mayes

Project Description

US30 Gutter repair / replace @ SR60, Alternative 3: Combination (Replace half of light excavator hours with skid steer loader. Eliminate compressor/jackhammer. Reduce labor by 25%. Eliminate heavy excavator and form materials. One day of slipform machine plus skid steer loader.)

MATERIALS

MATERIAL		UNIT	QUANTITY	UNIT COST	TOTAL COST
# 43030550 REBAR, #5, 5/8", EPOXY COATED	43030550	FT		$1.08	
# 42010412 LIMESTONE, #411	42010412	TN	3	$13.70	$41.10
# 42010157 LIMESTONE, #57	42010157	TN	49	$16.70	$818.30
# 42020361 CONCRETE QCI	42020361	CU.YDS	9.5	$150.00	$1,425.00
# 52030143 PLYWOOD, 3/4"X4'X8'	52030143	EA		$24.99	
# 52010602 LUMBER, PINE 2"X6"X12"	52010602	EA		$7.19	
# 42020435 CONCRETE, CLASS C	42020435	CY	16.5	$150.08	$2,476.32
# 42010505 LIMESTONE, #2	42010505	TN	2	$16.77	$33.54
# 42011105 CALCIUM FLAKES 50LB BAG	42011105	BG	2	$13.69	$27.38
# 42040100 EPOXY	42040100	EA		$16.00	
				Total Materials	$4,821.64

LABOR - Hours

NAME	QUANTITY	UNIT COST	TOTAL COST
HIGHWAY TECH 1	32	$30.75	$984.00
HIGHWAY TECH 2	184	$35.01	$6,441.84
HIGHWAY TECH 3	72	$39.31	$2,830.32
		Total Labor	$10,256.16

EQUIPMENT

SELECT HERE

EQUIPMENT (select under equip type - to right)	Eqp. Type	UNIT	QUANTITY	UNIT COST	TOTAL COST
PICKUP, 3/4 TON	222	mi	437	$0.78	$340.86
PICKUP, 1/2 TON	221	mi	48	$0.64	$30.72
DUMP TRUCK, 25000-35000GVW	254	mi	522	$3.79	$1,978.38
COMPRESSOR OVER 125CFM	372	hr		$32.23	
EXCAVATOR, LIGHT	470	hr	18	$39.11	$703.98
STAKE, 1 1/2 & OVER, STANDARD	233	mi	221	$2.59	$572.39
EXCAVATOR, HEAVY	471	hr		$49.95	
LOADER, SKID STEER	591	hr	26	$15.00	$390.00
SLIPFORM MACHINE	ASD	hr	8	$480.00	$3,840.00
				Total Equipment	$7,856.33

Pertinent planning information

MILES FROM GARAGE TO JOB	
ESTIMATED DAYS TO COMPLETE	
DETOUR REQUIRED?	
# of Structures or Lane Miles impacted by work	6.20

Total Labor	$10,256
Total Equipment	$7,856
Total Materials	$4,822

EIMS work order

County	Ashland
Route	30 / 60
SLM from	
SLM to	

TOTAL PROJECT COST $22,934

Project Cost per Lane Mile (structure) 3699.053226

Power Curber PWC5700-C	Contractor Low	Contractor High		Ashland County	Notes
Cost	$ 125,000	$ 300,000		$ 300,000	
Life Expectancy (Hours)	5,000	7,000		640	8 hours per project similar to ASD-30
Output (Feet/Minute)	5	10			
Output (Feet/Hour)	300	600			
Total Output (Feet)	1,500,000	4,200,000		9,480	1 project per year, 8 counties, 10 years
Total Output (Miles)	284	795		1.8	
Total Projects (Similar to ASD-30)	12,658	35,443		80	
Cost Per Linear Foot	$ 0.03	$ 0.20		$ 31.65	
Cost Per Hour	$ 17.86	$ 60.00		$ 468.75	
Fuel & Maintenance (Assume)	$ 10.00	$ 10.00		$ 10.00	
Total Cost Per Hour	$ 27.86	$ 70.00		$ 478.75	

ASD-30 Scenario (118.5 Feet)				
Slipform Machine (Hours)	0.40	0.20		
Roundup (Hours)	8	8		8

Savings Per Linear Foot	$ 17.03	
Savings Per Project	$ 2,018.00	
Break Even Point (Linear Feet)	17,616	almost 2X projected D03 output per 10 years
Break Even Point (Projects Similar to ASD-30)	149	

Compare to Standard Equipment	Cost Per Hour
Self Propelled Ditcher/Trencher	$ 27.65
Self Propelled Road Widener	$ 47.93
Pavement Milling Machine	$ 241.35

Typical Crew: 2 HT-3s, 3 HT-2s, 1 HT-1

Category	Actual Hours	60% (Demo/Removal)	One Day (Slipform)	Total	Hourly Cost	Actual	Alternative (Slipform)
HT-1	36.5	24	8	32	$ 30.75	$ 1,122.38	$ 984.00
HT-2	262.5	160	24	184	$ 35.01	$ 9,190.13	$ 6,441.84
HT-3	85.5	56	16	72	$ 39.31	$ 3,361.01	$ 2,830.32
					Total Cost	$13,673.51	$ 10,256.16

APPENDIX G:

Hydraulic Analysis

Hydraulic Analysis Report

Project Data

Project Title:

Designer:

Project Date: Thursday, December 07, 2017

Project Units: U.S. Customary Units

Notes:

Channel Analysis: Channel Analysis (Concrete)

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 2.0000 ft/ft

Side Slope 2 (Z2): 2.0000 ft/ft

Channel Width: 4.0000 ft

Longitudinal Slope: 0.0710 ft/ft

Manning's n: 0.0150

Depth: 0.5000 ft

Result Parameters

Flow: 35.8798 cfs

Area of Flow: 2.5000 ft^2

Wetted Perimeter: 6.2361 ft

Hydraulic Radius: 0.4009 ft

Average Velocity: 14.3519 ft/s

Top Width: 6.0000 ft

Froude Number: 3.9182

Critical Depth: 1.1183 ft

Critical Velocity: 5.1447 ft/s

Critical Slope: 0.0038 ft/ft

Critical Top Width: 8.47 ft

Calculated Max Shear Stress: 2.2152 lb/ft^2

Calculated Avg Shear Stress: 1.7761 lb/ft^2

Channel Analysis: Channel Analysis (Bituminous)

Notes:

Input Parameters

Channel Type: Trapezoidal
Side Slope 1 (Z1): 2.0000 ft/ft
Side Slope 2 (Z2): 2.0000 ft/ft
Channel Width: 4.0000 ft
Longitudinal Slope: 0.0710 ft/ft
Manning's n: 0.0150
Depth: 0.5000 ft

Result Parameters

Flow: 35.8798 cfs
Area of Flow: 2.5000 ft^2
Wetted Perimeter: 6.2361 ft
Hydraulic Radius: 0.4009 ft
Average Velocity: 14.3519 ft/s
Top Width: 6.0000 ft
Froude Number: 3.9182
Critical Depth: 1.1183 ft
Critical Velocity: 5.1447 ft/s
Critical Slope: 0.0038 ft/ft
Critical Top Width: 8.47 ft
Calculated Max Shear Stress: 2.2152 lb/ft^2
Calculated Avg Shear Stress: 1.7761 lb/ft^2

Channel Analysis: Channel Analysis (Erosion Control Mat, Type E)

Notes:

Input Parameters

Channel Type: Trapezoidal
Side Slope 1 (Z1): 2.0000 ft/ft
Side Slope 2 (Z2): 2.0000 ft/ft
Channel Width: 4.0000 ft
Longitudinal Slope: 0.0710 ft/ft
Manning's n: 0.0400
Depth: 0.5000 ft

Result Parameters

Flow: 13.4549 cfs
Area of Flow: 2.5000 ft^2
Wetted Perimeter: 6.2361 ft
Hydraulic Radius: 0.4009 ft
Average Velocity: 5.3820 ft/s
Top Width: 6.0000 ft
Froude Number: 1.4693
Critical Depth: 0.6311 ft
Critical Velocity: 4.0515 ft/s
Critical Slope: 0.0311 ft/ft
Critical Top Width: 6.52 ft
Calculated Max Shear Stress: 2.2152 lb/ft^2
Calculated Avg Shear Stress: 1.7761 lb/ft^2

Channel Analysis: Channel Analysis (Sod)

Notes:

Input Parameters

Channel Type: Trapezoidal
Side Slope 1 (Z1): 2.0000 ft/ft
Side Slope 2 (Z2): 2.0000 ft/ft
Channel Width: 4.0000 ft
Longitudinal Slope: 0.0710 ft/ft
Manning's n: 0.0400
Depth: 0.5000 ft

Result Parameters

Flow: 13.4549 cfs
Area of Flow: 2.5000 ft^2
Wetted Perimeter: 6.2361 ft
Hydraulic Radius: 0.4009 ft
Average Velocity: 5.3820 ft/s
Top Width: 6.0000 ft
Froude Number: 1.4693
Critical Depth: 0.6311 ft
Critical Velocity: 4.0515 ft/s
Critical Slope: 0.0311 ft/ft
Critical Top Width: 6.52 ft
Calculated Max Shear Stress: 2.2152 lb/ft^2
Calculated Avg Shear Stress: 1.7761 lb/ft^2

Channel Analysis: Channel Analysis (Rock Channel Protection)

Notes:

Input Parameters

Channel Type: Trapezoidal
Side Slope 1 (Z1): 2.0000 ft/ft
Side Slope 2 (Z2): 2.0000 ft/ft
Channel Width: 4.0000 ft
Longitudinal Slope: 0.0710 ft/ft
Manning's n: 0.0600
Depth: 0.5000 ft

Result Parameters

Flow: 8.9699 cfs
Area of Flow: 2.5000 ft^2
Wetted Perimeter: 6.2361 ft
Hydraulic Radius: 0.4009 ft
Average Velocity: 3.5880 ft/s
Top Width: 6.0000 ft
Froude Number: 0.9796
Critical Depth: 0.4936 ft
Critical Velocity: 3.6435 ft/s
Critical Slope: 0.0743 ft/ft
Critical Top Width: 5.97 ft
Calculated Max Shear Stress: 2.2152 lb/ft^2
Calculated Avg Shear Stress: 1.7761 lb/ft^2

Channel Analysis: Channel Analysis (Tied Concrete Block Mat)

Notes:

Input Parameters

Channel Type: Trapezoidal
Side Slope 1 (Z1): 2.0000 ft/ft
Side Slope 2 (Z2): 2.0000 ft/ft
Channel Width: 4.0000 ft
Longitudinal Slope: 0.0710 ft/ft
Manning's n: 0.0300
Depth: 0.5000 ft

Result Parameters

Flow: 17.9399 cfs
Area of Flow: 2.5000 ft^2
Wetted Perimeter: 6.2361 ft
Hydraulic Radius: 0.4009 ft
Average Velocity: 7.1760 ft/s
Top Width: 6.0000 ft
Froude Number: 1.9591
Critical Depth: 0.7495 ft
Critical Velocity: 4.3525 ft/s
Critical Slope: 0.0167 ft/ft
Critical Top Width: 7.00 ft
Calculated Max Shear Stress: 2.2152 lb/ft^2
Calculated Avg Shear Stress: 1.7761 lb/ft^2