Automated Cross-Slope and Drainage Path Method

Cross-slope, grade, and rut depth are roadway characteristics that affect a pavement's ability to drain surface runoff, which in turn affects the safe operation of vehicles in wet weather. Pavement surfaces can deteriorate from their original design due to wear and surface deformation, resulting in the development of areas prone to poor drainage and surface water entrapment. Therefore, it is critical to identify areas with poor drainage that can contribute to unsafe driving conditions, such as hydroplaning, so that FDOT can take correct measures quickly and provide safe driving conditions to the traveling public.

The Florida Department of Transportation (FDOT) materials research team developed a new analytical approach for roadway engineers to identify poorly drained areas characterized by long drainage paths -- a relative measure of a pavement's ability to adequately drain surface runoff. Engineers collect cross-slope, grade, and rut depth data with a Multi-Purpose Survey Vehicle (MPSV) consisting of an inertial roadway profiler van equipped with a Position Orientation System (POS) and a Differential Global Position System (DGPS) operated at highway speed (Figure 1).

Engineers process and analyze the data using the Automated Cross-Slope Analysis Program (ACAP), which was designed for use with Microsoft Excel using the Visual Basic for Applications (VBA) programming language (Figure 2). The program was developed to automate the data analysis and has significantly improved the overall efficiency of the automated process.

After engineers import the MPSV data into ACAP, they calculate the drainage path as a function of cross-slope, relative grade, and pavement width. Figure 3 shows the relationship of these characteristics and the drainage path. In general, as the cross-slope becomes shallower, the drainage path becomes larger. These poorly drained areas are characterized by relatively long drainage paths (Figure 4) and near-zero cross-slopes (Figure 5). ACAP gives users the ability to select and analyze discrete pavement segment(s) and generate summary statistics for further processing (Table 1). The results provide engineers with critical information to identify areas prone to poor drainage and to establish appropriate short-term and long-term solutions. ACAP also allows users to input threshold values and to report the discrete milepost locations where thresholds are exceeded (Figure 6). This technique has also been successfully used to assist district engineers in the pre-design phase of resurfacing and widening projects.

Measuring a pavement's ability to adequately drain surface runoff using the automated cross slope analysis program may be implemented during the design phase, during construction, or as part of a forensic investigation. The program may also be implemented at the network level to develop a database of existing pavement surface geometry and to serve as a catalyst for safety and resurfacing project development. The cost and length of time for implementing this technology depends on equipment availability or acquisition time and cost, the extent of deployment (project or network level), and availability of trained personel.

FIGURE 1   FDOT Multi-Purpose Survey Vehicle (MPSV)

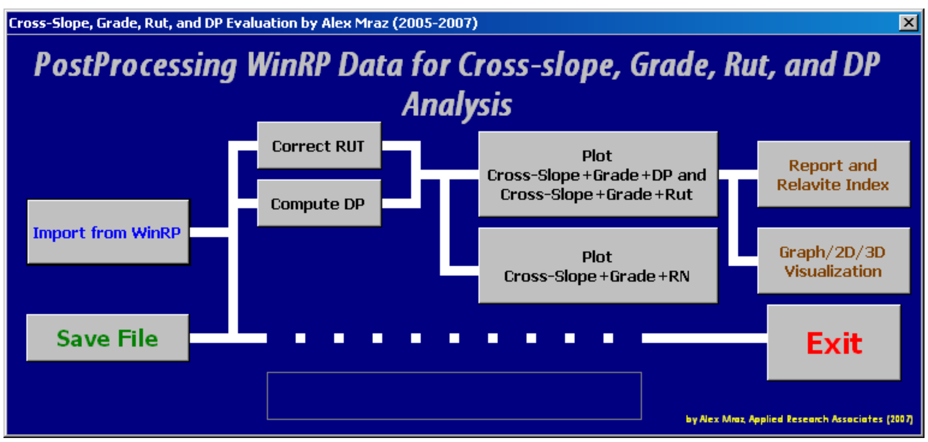

FIGURE 2 ACAP main menu

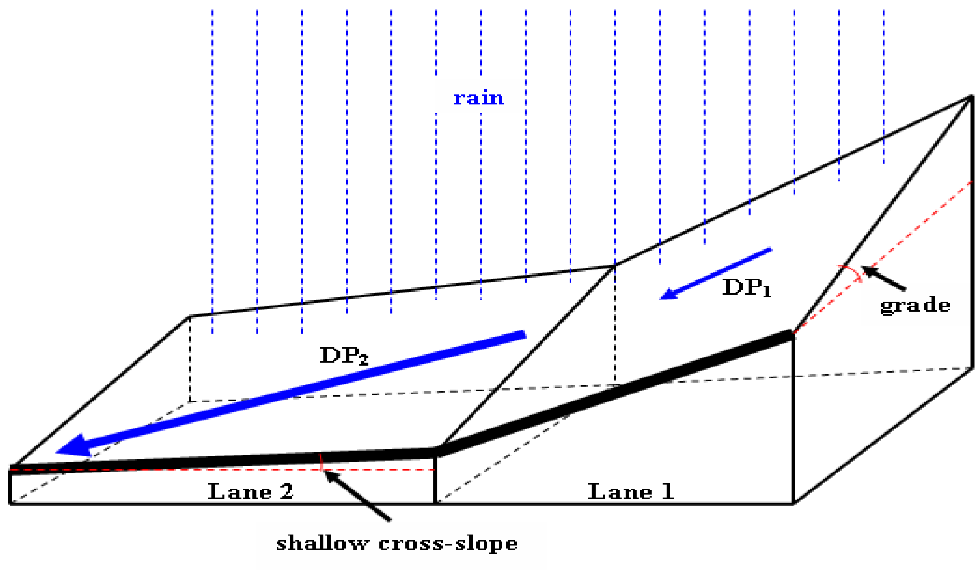

FIGURE 3 Long drainage paths (DP_2) due to shallow cross-slope in lane 2

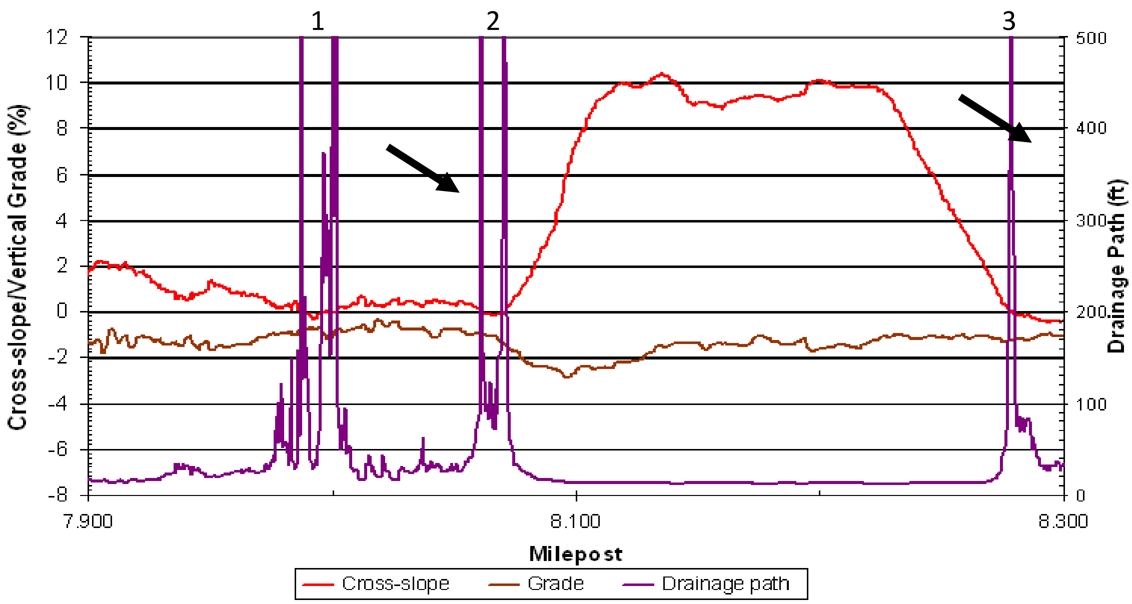

FIGURE 4 Long drainage path in (1) tangent section; (2) transition curve to superelevation; (3) transition curve to tangent

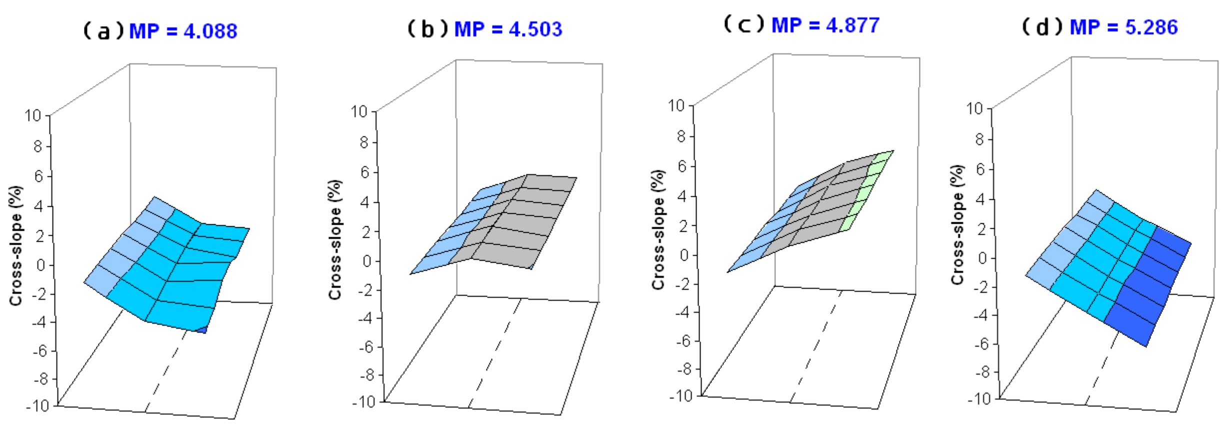

FIGURE 5 Cross slope in a two-lane roadway (a) Super elevation with flat cross-slope in right lane; (b) Super elevation with near-zero cross slope in right lane; (c) Left banking super elevation with adequate cross-slope in both lanes; (d) Right banking super elevation with adequate cross-slope in both lanes.

Milepost (MP)		Cross-slope (%)	Longitudinal Grade (%)	Drainage Path (ft)
6.32		2.36	-2.37	17
6.33		2.62	-1.61	14
6.34		3.11	-0.87	12
6.35		3.29	-0.56	12
6.36		3.44	-0.51	12
6.37		2.74	-0.40	12
6.38		4.24	-1.22	12
6.39		3.34	-0.59	12
6.4		3.53	-1.03	13
6.41		2.93	-0.61	12
6.42		1.81	-0.45	12
6.43		2.80	-0.68	12
6.44		2.66	-0.89	13
6.45		2.97	-0.82	12
6.46		2.78	-0.94	13
6.47		3.10	-0.96	13
6.48		2.62	-0.79	13
6.49		3.50	-0.91	12

Table 1 ACAP tabular output

REPORT

Road Number	72280	**Project Limit (Start)**	4.3
Road Name and County	SR-9, DUVAL Co	**Project Limit (End)**	2.3
Direction	Southbound	**Note**	0.01-mile interval reporting
FIN Number	213274-1-52-01	**Survey Date**	3/24/2010

Section: 2 (MP 3.95 to MP 3.2), L1, L2, and L3. L4 decceleration lane begins at MP 3.458 and ends at MP 3.358:

Super-Elevation.

L1 Cross-slope: Min= -3.2 %, Max= 2.3 %, Mean= -2.1 %, St.Dev.= 1.4 %.
L1 Drainage Path: Min= 12 ft, Max= 1130.2 ft, Mean= 40 ft.
L1 Rutting: Min= 0.00 inch, Max= 0.21 inch, Mean= 0.13 in, St.Dev.= 0.05 in.
L2 Cross-slope: Min= -3.4 %, Max= 1.8 %, Mean= -2 %, St.Dev.= 1.23 %.
L2 Drainage Path: Min= 13.6 ft, Max= 1200.1 ft, Mean= 29.8 ft.
L2 Rutting: Min= 0.00 inch, Max= 0.37 inch, Mean= 0.21 in, St.Dev.= 0.05 in.
L3 Cross-slope: Min= -2.4 %, Max= 2.8 %, Mean= -1.1 %, St.Dev.= 0.93 %.
L3 Drainage Path: Min= 12 ft, Max= 1092.1 ft, Mean= 21.7 ft.
L3 Rutting: Min= 0.00 inch, Max= 0.3 inch, Mean= 0.18 in, St.Dev.= 0.07 in.
L4 Cross-slope: Min= 0.6 %, Max= 4.4 %, Mean= 3.2 %, St.Dev.= 1.02 %.
L4 Drainage Path: Min= 12.2 ft, Max= 29.2 ft, Mean= 13.4 ft.
L4 Rutting: Min= 0.07 inch, Max= 0.48 inch, Mean= 0.17 in, St.Dev.= 0.12 in.
L4 Average Vertical Grade= -1.1 %.

User Note: L3 lane is not fully superelevated (Cross-slope is between 1% and 2%). Rutting in all lanes is up to 0.25 inch with L2 up to 0.35 inch. Cross-slope in L3 steadily rises from 0.5% up to 6% and splits off L3 lane which has negative Cross-slope.

FIGURE 6 Threshold-based ACAP report