

IAPA Research Paper

**Asphalt Concrete Pavement Drainage Using DRIP (Drainage Requirements in Pavement)
Software**

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January 2016

Introduction:

Efficient drainage of pavement is necessary for the long-term performance of a road. Water related issues dramatically reduce the life of a pavement section. Poor drainage combined with temperature fluctuation cause pot holes, cracking, pumping, curling, and several other problems. In order to check the drainage capabilities of designed roads, a program called Drainage Requirements in Pavements (DRIP) was developed. DRIP, which can be downloaded for free online, allows the user to toggle through several tabs in order to give the program as much information about the designed road and existing conditions as possible. This allows the programs to determine whether or not several design factors are satisfactory or not. The following pages show the step by step process of using the software. It is beneficial for the user to have the software open and follow along with the example. This is just one general example that gives a broad view of how to use the program.

Example Problem Statement:

A crowned two way asphalt concrete roadway has a pavement width of 24 ft. The road has 10 ft HMA shoulders on each side. The road is crowned with a 2 percent slope in both the longitudinal and lateral directions. The pavement is made with 9 inches of PCC with joint spacing every 15 ft. The road has a permeable base composed of AASHTO #57 (sieve analysis shown in Figure 3) and has a unit weight of 100 pcf and a specific gravity of $G = 2.25$. Determine if a design with a permeable base thickness of 6 inches is satisfactory. The roadway lies on native soil. The sieve analysis for the native soil is shown in Table 1. Determine if an additional separator layer is needed. If a 4 inch diameter corrugated pipe is used as an edge drain, determine the outlet spacing requirement. If the design is not practical, change the design of the pipe. Meltwater calculations can be neglected.

Table 1. Sieve Analysis of Subgrade

SIEVE NO.	PERCENT PASSING
No.4	92
No. 10	67
No. 20	55
No. 50	42
No. 200	31

Roadway Geometry

Step 1 – Start by determining if the proposed roadway is crowned or if it has a uniform slope. In this case, the roadway is crowned so Cross-slope (Geometry A) is selected.

Step 2 – Input the values for the total width of the lanes (b) and the width of the shoulders (c).

Once the values are recorded, the program will compute the width of permeable base (W). In the case of the example:

$$b = 24 \text{ ft}$$

$$c = 10 \text{ ft}$$

$$W = 22 \text{ ft}$$

Step 3 – Record the values for the longitudinal slope (S) and the transverse slope (S_x). Once the values for are recorded, the program will compute the resultant slope (S_R). In the case of the example:

$$S = .02 \text{ ft/ft}$$

$$S_x = .02 \text{ ft/ft}$$

$$S_R = .0283 \text{ ft/ft}$$

Step 4 – After all the previous values have been inputted L_R can be automatically calculated by the program. In this case:

$$L_R = 31.11 \text{ ft}$$

The Roadway Geometry tab is now completed. The program shows all formulas it used for computations and visual representations of roads so that the user can verify the answers. A screenshot of the completed Roadway Geometry tab is shown in Figure 1. The user then should move to the Inflow tab.

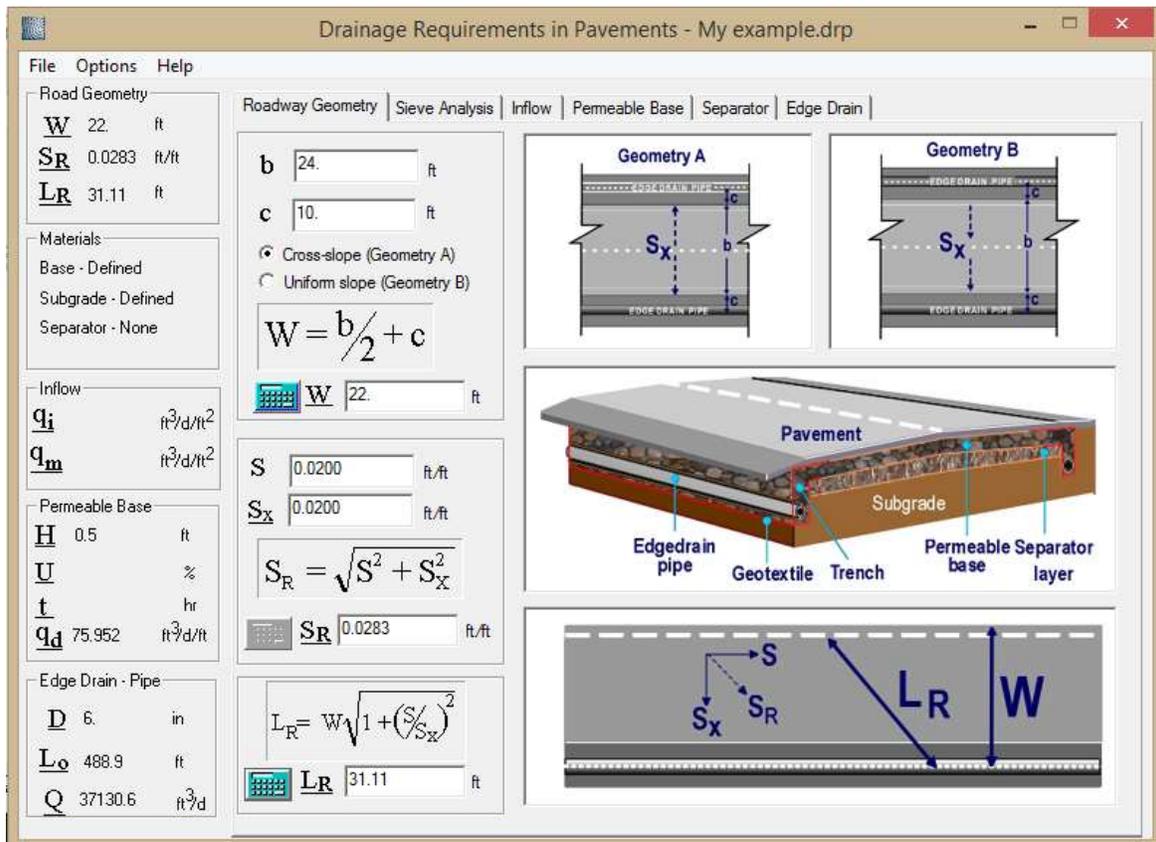


Figure 1. Roadway Geometry Tab

Inflow

Upon clicking on the Inflow tab, the user sees some values already inputted. The default value for I_c is $2.4 \text{ ft}^3/\text{ft}/\text{day}$. W_c and W have been carried over from the Roadway Geometry tab. The permeability of pavement (k_p) is defaulted as $0 \text{ ft}/\text{day}$.

Step 1 – The user determines if he or she wants to solve the problem using the Infiltration Ratio Method or the Crack Infiltration Method. For this example, the Crack Infiltration Method was selected.

Step 2 – Input the values for the number of cracks (N_C) and the spacing of transverse joints (C_S). N_C is equal to the number of contributing lanes plus one. C_S is given in the problem statement.

For this example:

$$N_C = 3 \text{ cracks}$$

$$C_S = 15 \text{ ft}$$

Step 3 – After all values have been recorded, the inflow (q_i) can be calculated automatically by the program. For this example:

$$q_i = .41455 \text{ ft}^3/\text{day}/\text{ft}^2$$

Step 4 – The user will determine if he or she should include meltwater in the inflow calculations. If the design calls for it, the stress and inflow can be calculated by using the known properties of the subgrade. However, for the example, meltwater can be neglected. The Inflow Tab is now complete. A screenshot of the completed Inflow Tab is shown in Figure 2. The user can then move on to the Sieve Analysis tab.

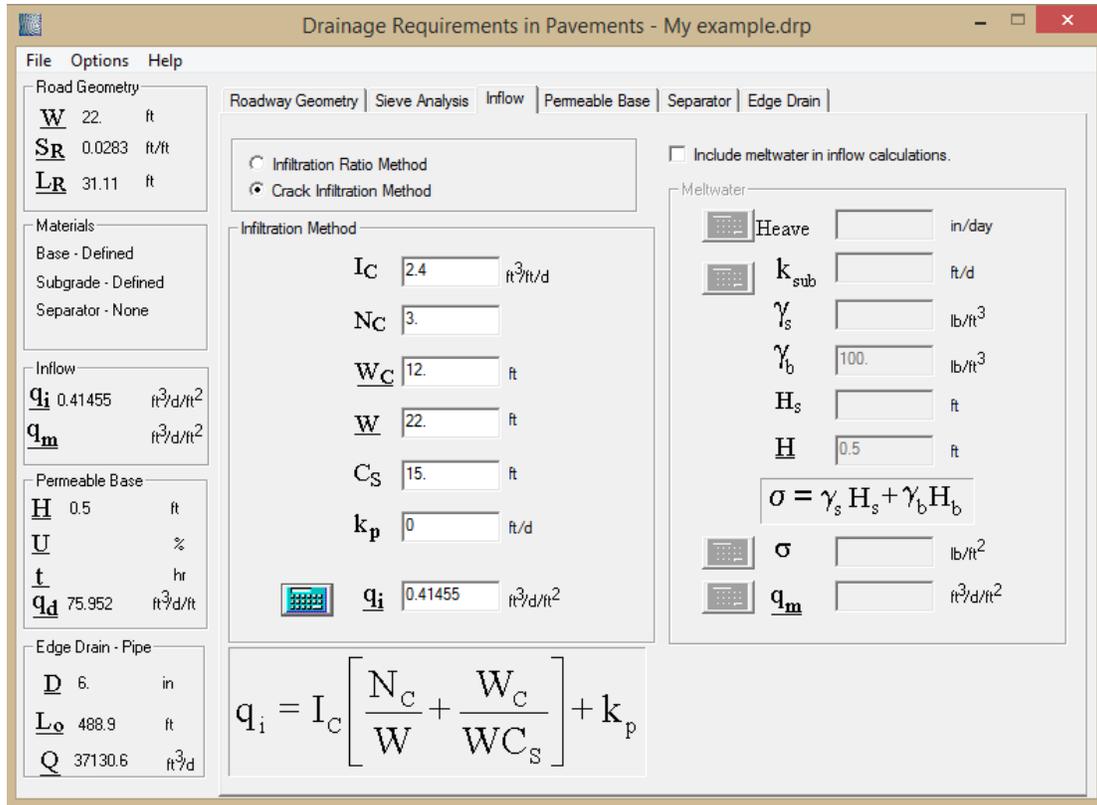


Figure 2. Inflow Tab

Sieve Analysis

Step 1 – The user should select the “base” button. Looking back at the problem statement, the base is made of AASHTO #57. The user should click the dropdown arrow of the Material Library and select the material. Selecting the material will display the percent passing for each sieve. The program now has the information it needs for the Gradation Analysis.

Step 2 - The unit weight of the base was given in the problem as 100 pcf, and the specific gravity was given as 2.25. Inputting these values allows the program to calculate the porosity (n) and permeability (k). For this example:

$$n = .288$$

$$k = 2891.501 \text{ ft/d}$$

Step 3 – The user should select the subgrade ratio button. The problem statement gives the sieve analysis of the subgrade. The user can input the values for the percent passing of each sieve given. After recording these values, the program can complete the gradation analysis for the subgrade. It should be noted for this specific problem, the unit weight and specific gravity of the subgrade is not given. Therefore the porosity and permeability of the subgrade cannot be determined. However, the user will see that those values are not needed to complete this problem. The problem statement asks for the user to determine if a separator layer is needed. Because of this, one is not included in the sieve analysis. Later in the program it will be determined if a separator layer is needed or not. A screenshot of the completed Sieve Analysis for the base is shown in Figure 3.

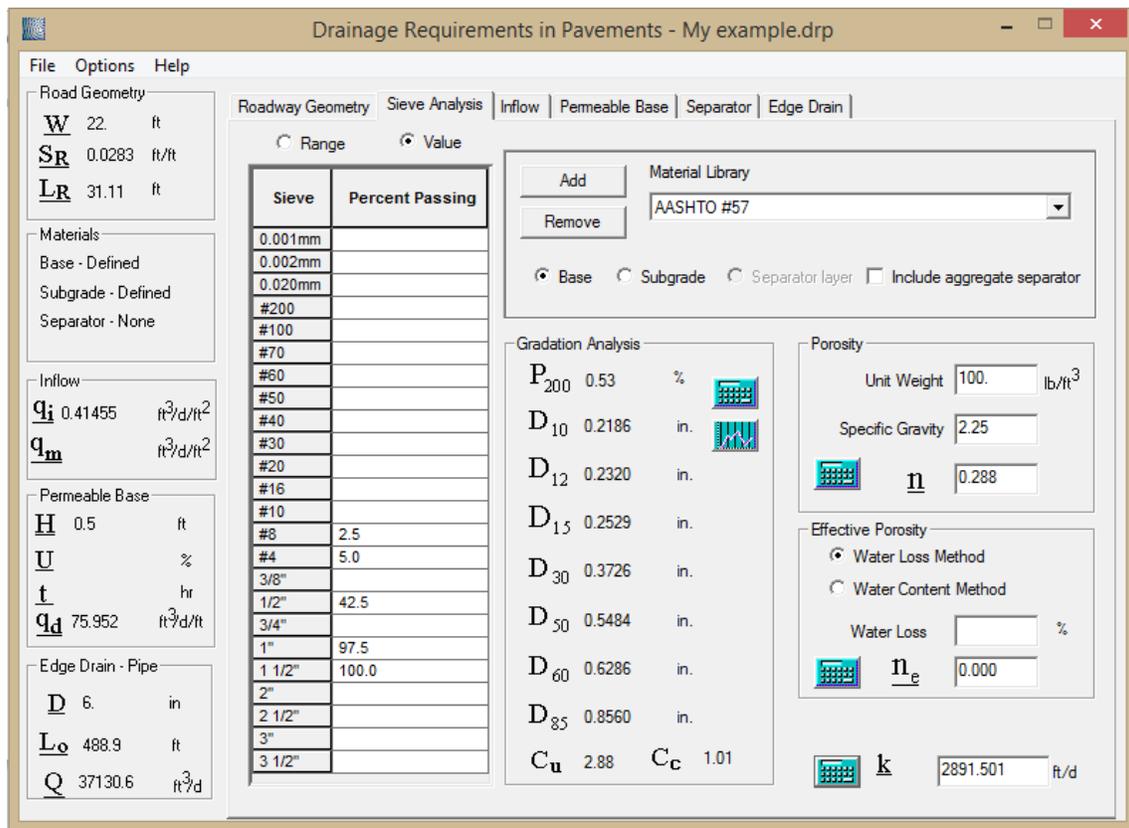


Figure 3. Sieve Analysis Tab

Permeable Base

Step 1 – Depending on what the user is trying to determine, he or she can either use Time-to-Drain analysis or Depth-of-flow analysis. Time-to-Drain allows the user to solve for the amount of time for 50% or 85% drainage. Depth-of-flow allows the user to determine the required thickness or the permeable base. This problem asks whether a certain thickness is satisfactory, so the user should select Depth-of-flow.

Step 2 – The inflow (q_i) has been carried over from the Inflow Tab, the permeability (k) has been carried over from the Sieve Analysis Tab, the resultant slope (S_R) has been carried over from the Roadway Geometry Tab, and the resultant length (L_R) has been carried over from the Roadway Geometry Tab. The program now has all the data it needs to determine the minimum permeable base thickness (H_{min}). For this example:

$$H_{min} = .12215 \text{ ft}$$

Because H_{min} is less than the proposed depth of 6 inches, the design is satisfactory.

Step 3 – The proposed value for the permeable base thickness (H) should be inputted. The program now can calculate the flow capacity of the permeable base (q_d). For this example:

$$q_d = 75.952 \text{ ft}^3/\text{day}/\text{ft}^2$$

The Permeable Base Tab is now complete. A screenshot of the completed tab is down in Figure 4.

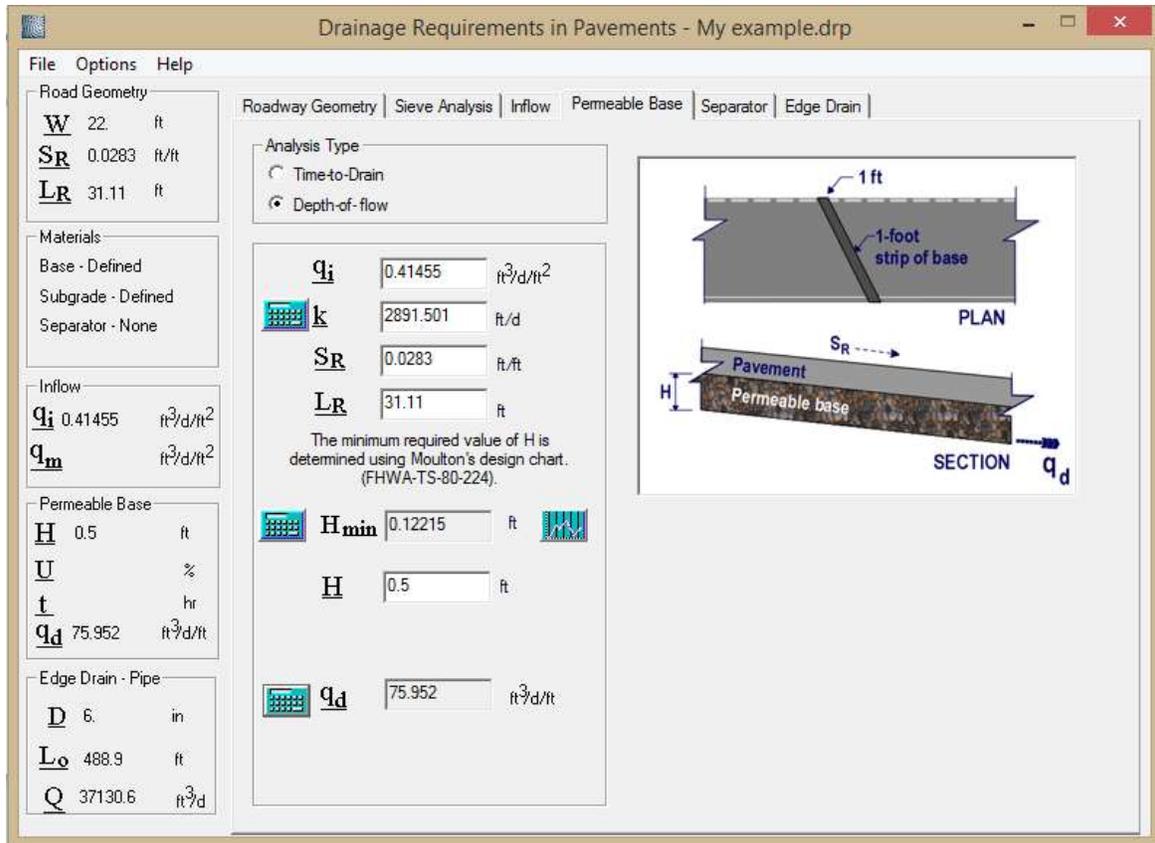


Figure 4. Permeable Base

Separator Tab

Step 1 – First the user must choose an analysis type. The options include analysis with an aggregate separator, geotextile separator, or no separator. The problem statement asks whether a separator is needed or not. Therefore, the user should select “no separator.”

Step 2 – The D_{15} and D_{50} values for both the base course and subgrade have been carried over from the Sieve Analysis Tab. These are necessary for the program to calculate the necessity of a separator layer. By clicking on the scale, the program indicates if the design passes or fails. For this example the design passes. Therefore, no separator layer is needed.

The Separator Tab is now complete. A screenshot of the completed Separator Tab is shown in Figure 5. The user can now move on to the final tab, the Edge Drain Tab.

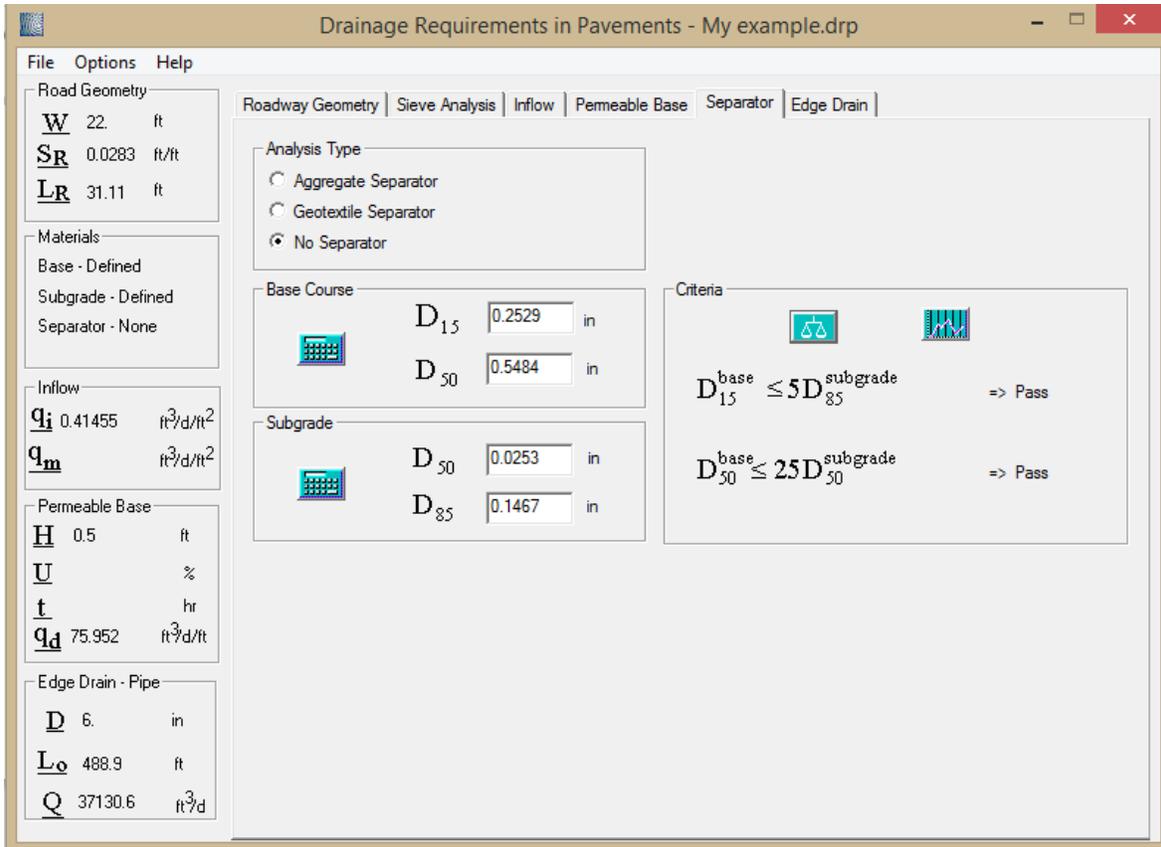


Figure 5. Separator Tab

Edge Drain

Step 1 – The user first must select the Edge Drain Type. Because the problem states that a corrugated pipe is to be used, the user should select “pipe”. Also the typical roughness coefficients for underdrain are shown on the right of the page. The user should select corrugated as indicated in the problem.

Step 2 – The slope has been carried over from the Roadway Geometry Tab and the roughness coefficient has been inputted by selecting the corrugated pipe. Next the user must input the pipe diameter (D). For this example:

$$D = 4 \text{ in}$$

Step 3 – Select a Discharge Rate Approach. Any of the approaches will solve for the flow capacity of the pipe (Q), but because this example deals with the thickness of the permeable base, the Permeable Base Approach should be chosen. This automatically carries the flow capacity of the permeable base from the Permeable Base Tab.

Step 4 – All necessary values for the program to compute the flow capacity of the pipe are included. For this example the program finds the capacity to be:

$$Q = 12593.7 \text{ ft}^3/\text{day}$$

The program then can compute the outlet spacing (L_o). For a 4 inch diameter:

$$L_o = 165.8 \text{ ft}$$

A screen shot of the completed 4 inch Edge Drain Tab is shown in Figure 6.

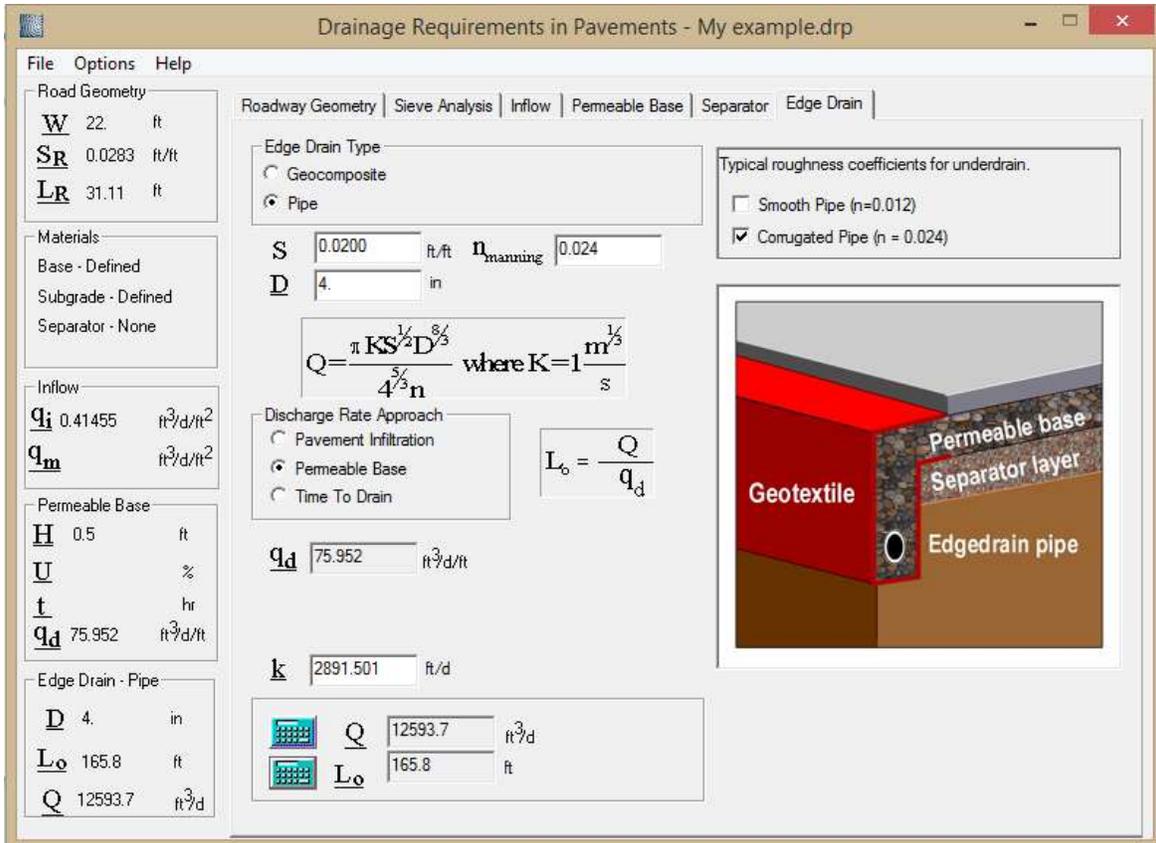


Figure 6. 4 inch Edge Drain Tab

Step 5 - From a design standpoint, this is satisfactory. However in order to make the design more practical/economical, larger spacing between outlets would be preferred. By changing the diameter of the pipe and leaving the rest of the values unchanged, the user can increase the flow capacity of the pipe. Thus, the outlet spacing distance is increased. An increase to a 6 inch pipe would increase Q and L_o . This is a much more practical design

$$Q = 37130.6 \text{ ft}^3/\text{day}$$

$$L_o = 488.9 \text{ ft}$$

The completed 6 inch Edge Drain Tab is shown in Figure 7.

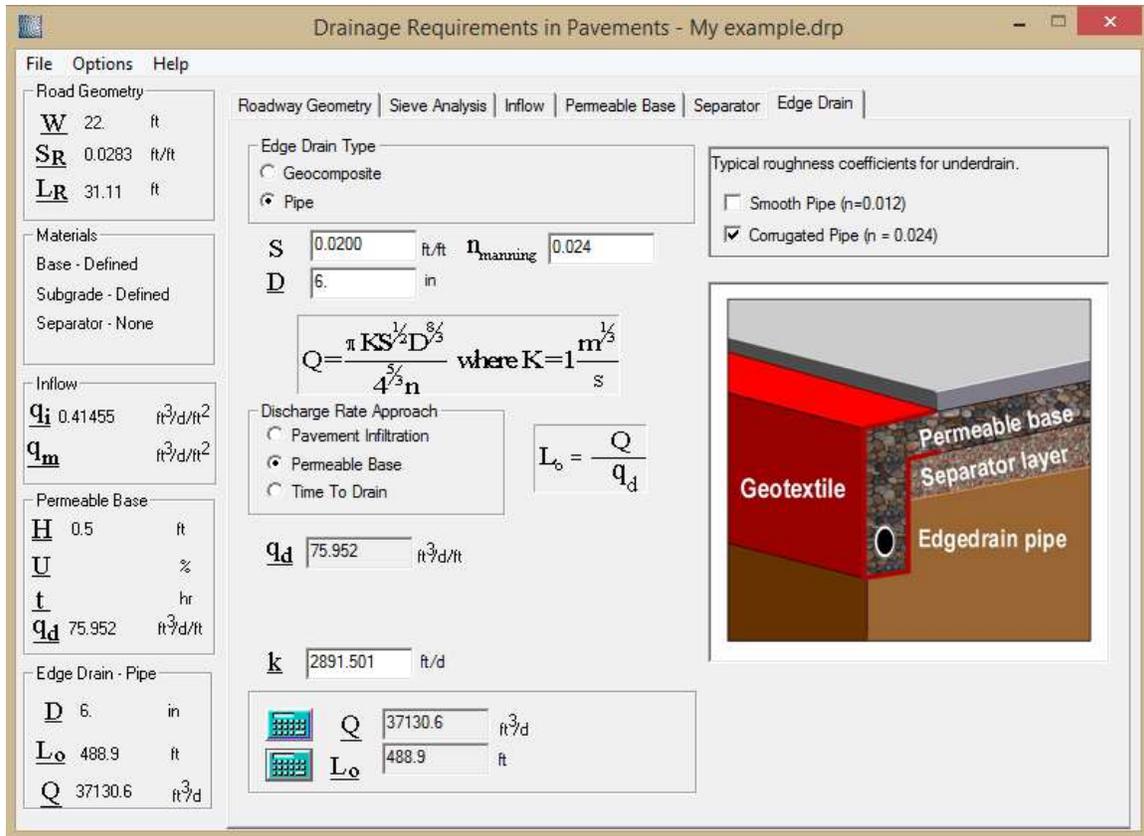


Figure 7. 6 inch Edge Drain Tab

Comments:

The use of the DRIP program allowed the user to easily determine that a design with a 6 inch permeable base was satisfactory. It showed that no separator layer was needed. It also showed practical outlet spacing for the edge drain. Every feature the problem asked for was easily obtained by inputting the given values. The program allows the user to use the known values from his or her project and combine those values with desired design criteria and easily obtain results. Once the user is proficient with the program, complex drainage calculations can be obtained in a very short amount of time.

References

Arika, C. N., Canelon, D. J., and Nieber, J. L. (2009) "Subsurface Drainage Manual for Pavements in Minnesota." *Minnesota Department of Transportation Research*, 2009-17.

ARA, Inc., ERES Division. (2004). "Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures." Appendix TT: Drainage Requirement in Pavements (DRIP) Microcomputer Program User's Guide. *National Cooperative Highway Research Program Transportation Research Board National Research Council*. Final Document