CIVL 4155/6155
Spring 2019
End-of-Semester Design Problem

We are replacing an 8-mile stretch of Interstate 40 in Madison County that extends from a point 0.1 miles east of US-70 to a point 0.3 miles east of the Madison-Henderson County line. The highway has 2 travel lanes in each direction separated by a grass median.

Traffic count data from Spring 2019 shows the following distribution of eastbound vehicles along with the appropriate TDOT load equivalency factors for each vehicle class:

Vehicle Class	Vehicle Count	Flexible LEF	Rigid LEF
1–2	16,302	0.001	0.001
3	3432	0.004	0.005
4	131	0.300	0.300
5	481	0.170	0.170
6–7	515	0.700	1.000
8	824	0.700	0.780
9–13	6915	1.100	1.7800
1-way ADT =	28,600		

Traffic has been growing at a rate of 2.5% per year since Spring 2016 and is expected to continue growing at that rate in the future. Construction is not expected to be finished until Spring 2024, so take that into account when you determine the number of ESALs that will accumulate from the time the pavement opens to traffic until the end of its design life 20 years later.

The percentage of trucks in the design lane can be estimated based on the number of lanes and the one-way ADT using this table provided by TDOT:

1-way ADT	2 lanes	3 lanes	4 lanes
5,000 or less	90%	75%	70%
5,000–10,000	80%	70%	65%
10,000–15,000	75%	65%	60%
15,000–20,000	75%	65%	55%
20,000–30,000	70%	60%	50%
30,000–70,000	65%	60%	50%

In Tennessee we don’t have much of a problem with winter freeze and spring thaw, so TDOT uses a single design subgrade modulus year-round. For this stretch of highway, the subgrade modulus should be estimated based on a CBR of 5.

The mainline pavement will consist of two 12' wide travel lanes. There will also be a 4' wide inside shoulder and a 10' wide outside shoulder. TDOT uses 2% of the mainline ESALs to do the shoulder design. This is meant to account for vehicles wandering onto the shoulder.

Everyone will design a flexible pavement using the AASHTO design method with the goal of achieving the lowest possible construction cost per mile. Design for an initial serviceability level of 4.2, a terminal serviceability level of 3.0, and 98% reliability.

You should include subsurface drainage in the form of a permeable base layer in your design. Assume the drainage layer (permeable base) will be saturated no more than 15% of the time and, once saturated, it should be designed so as to drain in 10 hours or less.

Assume that the only source of water is infiltration through the pavement surface. The pavement will be constructed with a 2% cross-slope and everything drains to a swale located beyond the outside shoulder. Since the highway will traverse gently rolling terrain, assume that the maximum longitudinal slope of the pavement is 2%. Since this represents the worst case, you should design the entire pavement using this value. Since the same edge drain collection system will apply to all of the design variants, there is no need to include it here.

The materials available for your flexible pavement design are as follows:

Layer	Material	Layer Coefficient	Min Lift Thickness	Max Lift Thickness
Asphalt Concrete	Asphalt wearing course	0.44	1.5"	3"
	Asphalt binder course	0.44	2"	4"
	Aggregate-bituminous base (ABB)	0.42	4"	8"
Permeable Base	Asphalt-treated permeable base (ATB)	0.21	4"	8"
	Crushed stone (1½") base course	0.14	4"	8"
	Crushed stone (¾") base course	0.12	4"	8"
Subbase	6% lime-stabilized soil subbase	0.15	8"	8"
	Bank-run gravel subbase	0.08	6"	12"

You must have at least 1½" of asphalt wearing (surface) course in order to provide a smooth ride and you must have at least 2" of binder course below it. The rest of the asphalt-bound surface can be made of additional asphalt binder course or aggregate-bituminous base course material.

If your design calls for asphalt layers thicker than the maximum values indicated in the table, the asphalt will have to be placed in multiple lifts. Every time you place one layer of asphalt over another layer, you must include a tack coat in between. The tack coat is a sprayed-on asphalt emulsion applied at a rate of 0.10 gallons of asphalt cement per square yard of pavement surface.

The asphalt-treated permeable base (ATB) has a permeability of 3000 ft/day. The crushed stone bases both have a D_{10} of 0.30 mm (i.e., a No. 50 sieve) and 2% passing the No. 200 sieve. The coarser stone has a porosity of 0.43 and the finer stone has a porosity of 0.39.

The permeable base materials also have minimum and maximum lift thicknesses. If you design a base course thicker than the values listed in the table above, you will have to install the material in multiple lifts. Thus, if you need (for example) 12" of crushed stone, you will have to actually place the stone as two 6" lifts and determine the cost of each lift separately. Nothing is required in between layers of stone since they "stick" together through aggregate interlock. Also, no tack coat is used between multiple lifts of ATB because that would destroy its permeability.

Once you've provided for an asphalt-bound layer (consisting of wearing course, binder course, and an optional ABB course) and a permeable drainage blanket (of crushed stone or ATB), the rest of the pavement can be constructed from additional crushed stone (if needed for strength), or gravel subbase, or lime-treated soil subbase. You do not have to have a subbase, but if you do, you must choose one or the other; you can't use two different subbase materials.

The amount of lime used to stabilize a soft, wet subgrade is typically 4 to 6 percent of the soil mass. The depth to which the subgrade is amended depends on the quality of the soil and ranges from 6 inches for marginal soils to 12 inches for the very worst soils.

Based on laboratory tests, it is recommended that, if you stabilize for this project, add 6% lime to a depth of 8 inches. That means you either include an 8-inch lime-stabilized subbase or you don't. You don't get to "design" the layer thickness as you would the other pavement layers. If you choose to lime stabilize, assume the resilient modulus of the stabilized subgrade is twice that of the unamended subgrade.

In addition to the flexible pavement, CIVL 6155 students will design a JPCP pavement for this site. Use a 30-year design life and an initial serviceability index of 4.5. You will have to evaluate designs using un-tied asphalt shoulders and tied concrete shoulders and decide which is least expensive. You will have to determine the size and spacing of the tie bars, but you will not have to design the dowel bars. For drainage purposes, you must include <u>either</u> a crushed stone base course <u>or</u> an asphalt-treated permeable base course beneath the travel lanes and shoulders. There will only be one base course and it will be 6" thick. There is no bedrock within 10 feet of the surface. The paving contract will specify a concrete compressive strength of 5000 psi and a modulus of rupture of 650 psi.

To determine the appropriate costs, you will use the excerpts provided from the RS Means publication *Site Work and Landscape Cost Data*. Note that everything is priced per square yard *except* the tie bars, which are priced per bar. CIVL 6155 students can ignore the cost of dowel bars and joint sealant because all of the concrete designs will include those features. But the cost of tie bars must be included in order to accurately compare asphalt shoulders (which aren't tied to the concrete pavement) to concrete shoulders (which are tied to the concrete pavement).

Your written project report should include a clearly articulated design approach as well as a description of the various design iterations and complete calculations for ***one*** of the design iterations. The report should clearly show the ***final*** thickness design for the traffic lanes and shoulders and the final cost per mile of highway, but I also want to be able to see how you calculated your costs and what values you used from the RS Means guide.

Keep in mind that the top of the pavement and the bottom of the drainage layer must be continuous across the entire width of the pavement. If the asphalt-bound layer is thinner on the shoulders than the mainline pavement, you will have to make up the difference with other (cheaper) materials.

Your report is due at the start of the final exam period for this class, which is Wednesday, **May 1st** at 10:30 am. During the exam period, everyone will briefly present their solution to the class. These ***5-minute*** oral presentations should explain (a) any assumptions you made, (b) the design W_{18} and total SN value you used for the mainline pavement and the shoulders, (c) the final thickness design for the mainline pavement and the shoulders (including subsurface drainage), and (d) the final cost per mile of highway. You should clearly show how you arrived at your final cost during the presentation.

Make sure you clearly state in your report any assumptions you had to make in order to complete this design. If you have specific questions, please e-mail them to me. I will post both the questions and the answers on the website under "Q&A" so everyone has access to the same information.

Good luck.