CE 3500: Exam 2

Friday, April 23

10:00 – 10:50 AM

Name _____

Instructions:

- **SHOW ALL WORK** unless instructed otherwise. No shown work means no partial credit!
- If you require additional space, you may use the back of each sheet and/or staple additional pages to the end of the exam.
- If you need to make any additional assumptions, state them clearly.
- You may use one regular-sized sheet of notes; please turn in the notes with your exam. No additional resources are permitted.
- The number of points associated with each part of each problem is indicated.

Problem	Points	Possible
1		10
2		15
3		15
4		10
TOTAL		50

Problem 1. Short answer. (10 points). Answer the following questions completely, but concisely (emphasis on **short** answer). You may draw a figure if it would be helpful.

1. (4) Draw a diagram labelling the four layers in a flexible pavement.
2. (3) State the principle of user equilibrium, and specify which step of the four-step model uses it.
3. (3) Describe a situation where a perfectly good engineering/technological solution to a transportation problem may be unacceptable for political or other nontechnical reasons.

Problem 2. (15 points.) My name is Walters, Sam Walters, and I'm a private eye. I took an inheritance case last week from a dame named Elisabeth McDaniels. She made sure I knew it was Elisabeth spelled with an 's,' but to me the case has spelled nothing but trouble. I'm trying to track down the Sicilian Pigeon, a jeweled figurine worth tens of thousands, and the only clue I've got so far is a scrap of paper with an equation on it. You see, the other heir is a transportation engineer, and he's trying to do everything he can to keep the Pigeon from passing to Elisabeth.

He works in the planning department, and the paper has a trip generation linear regression equation for one of the zones here. His handwritten notes explain the code: he's hiding, and his address can be found by answering the questions below. The equation is

$$P = 0.20 + (4.8 \times 10^{-5})I + 0.40n + 0.10n_C$$

where P is total household productions, I the household income, n the total household size, and n_C the number of children. This zone has 31,367 households with an average income of \$30,000 and 3.1 members, 1.2 of which are children. The answers to the three questions give his ZIP code, building address, and number of his street, respectively.

1. (5) Calculate the total number of trips produced by this zone.
2. (5) How much would household income need to rise for a household to increase its trip productions by 0.3?
3. (5) How many children would have to be added to a household to increase its trip productions by 1?

Problem 3. (15 points). I find the address, and follow the other heir as he drives away. His name is Snake Eyes Malone, and while I've dealt with him before, he's the type who likes to do the dealing himself, and is feeling generous if he lets you shuffle beforehand. He's a slippery guy, almost as slippery as the road is getting from the rainfall the last few days. As he passes over a crest vertical curve, I lose sight of him. When I crest the curve and begin a 3% downgrade, I see skid marks leading to Malone's car, which has crashed, leaving him unconscious. Was this an accident, or did someone want him out of the way? Donning my trench coat and fedora, I step out into the rain and begin my investigation.

1. (2) Traffic is uniform, with a volume of 1000 veh/hr and a density of 20 veh/mi. What speed was he traveling at?

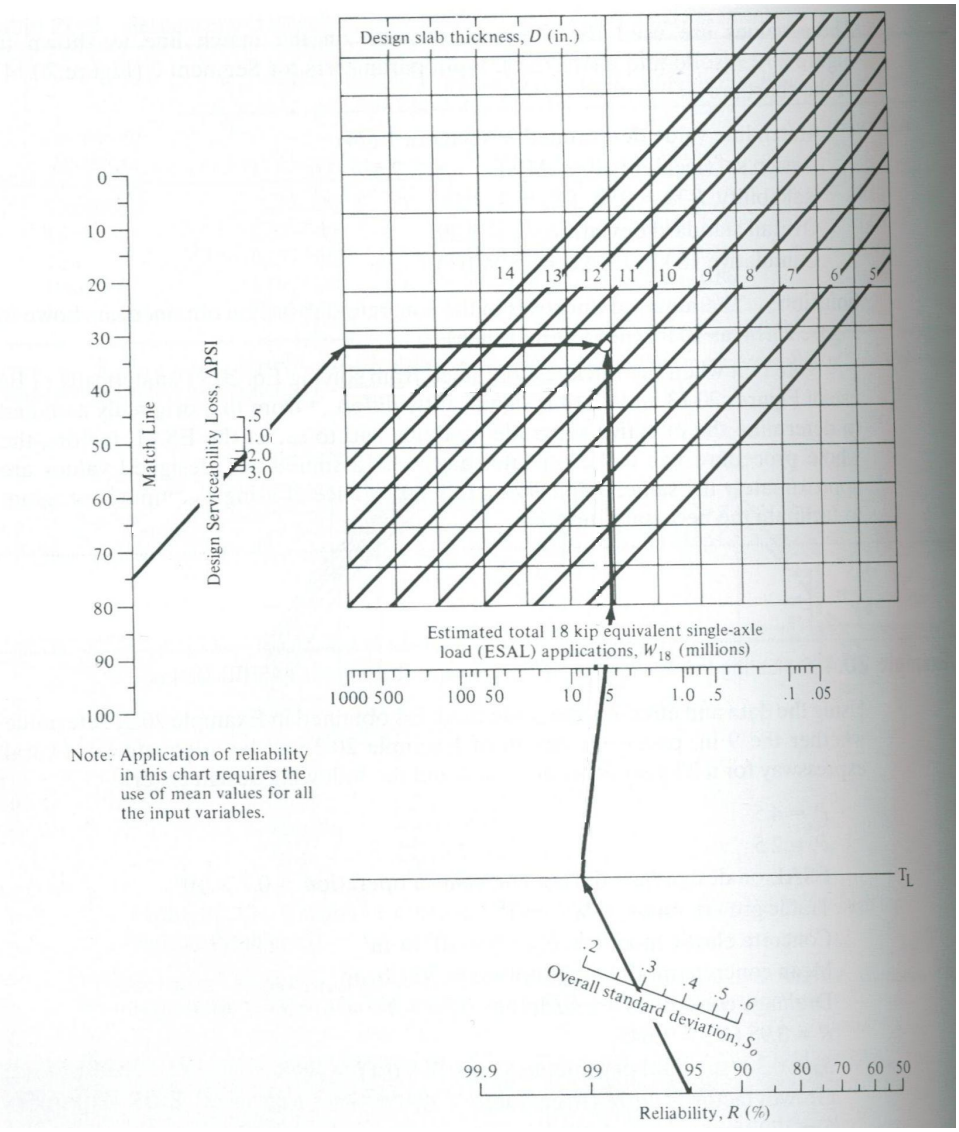
2. (3) Using a map, I measure the horizontal length of the skid marks to be 1235 ft. Assuming that he was braking uniformly at the maximum allowable rate and came to a stop at the end of the skid marks, what is the coefficient of friction in the rainy weather?

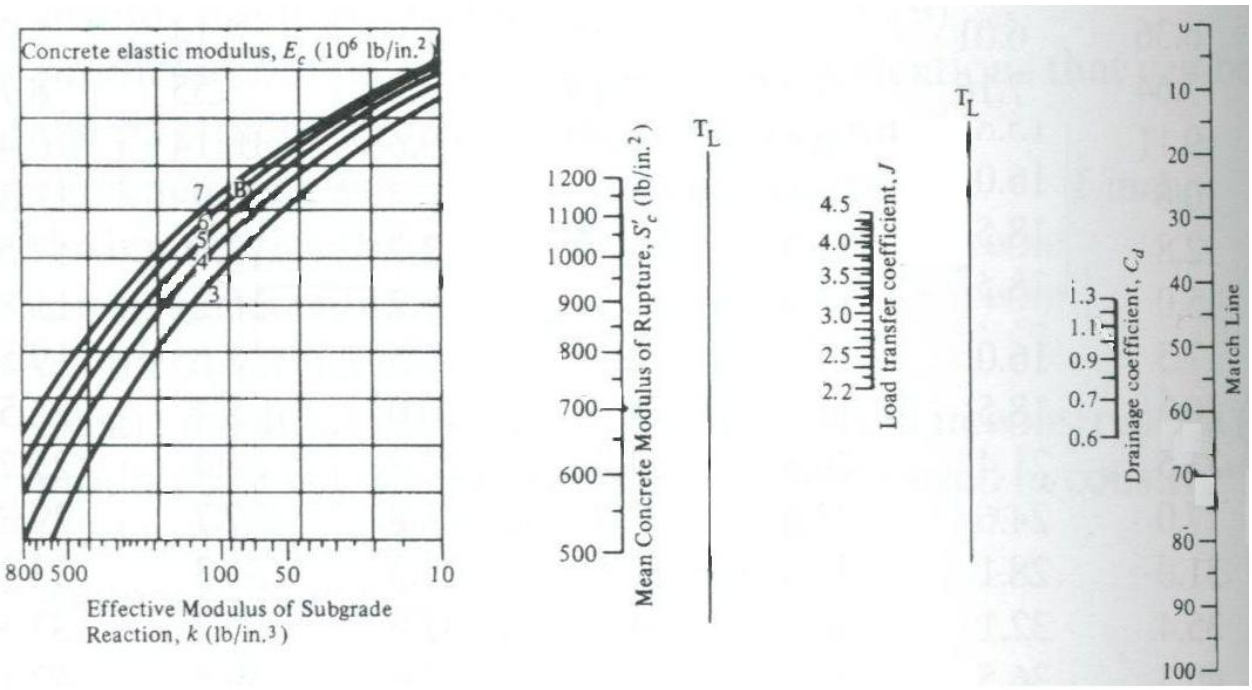
3. (4) The curve length is 2500 feet, and the initial grade is 3% uphill. Assuming the curve length is shorter than the necessary stopping sight distance, what was the design sight distance for this curve?

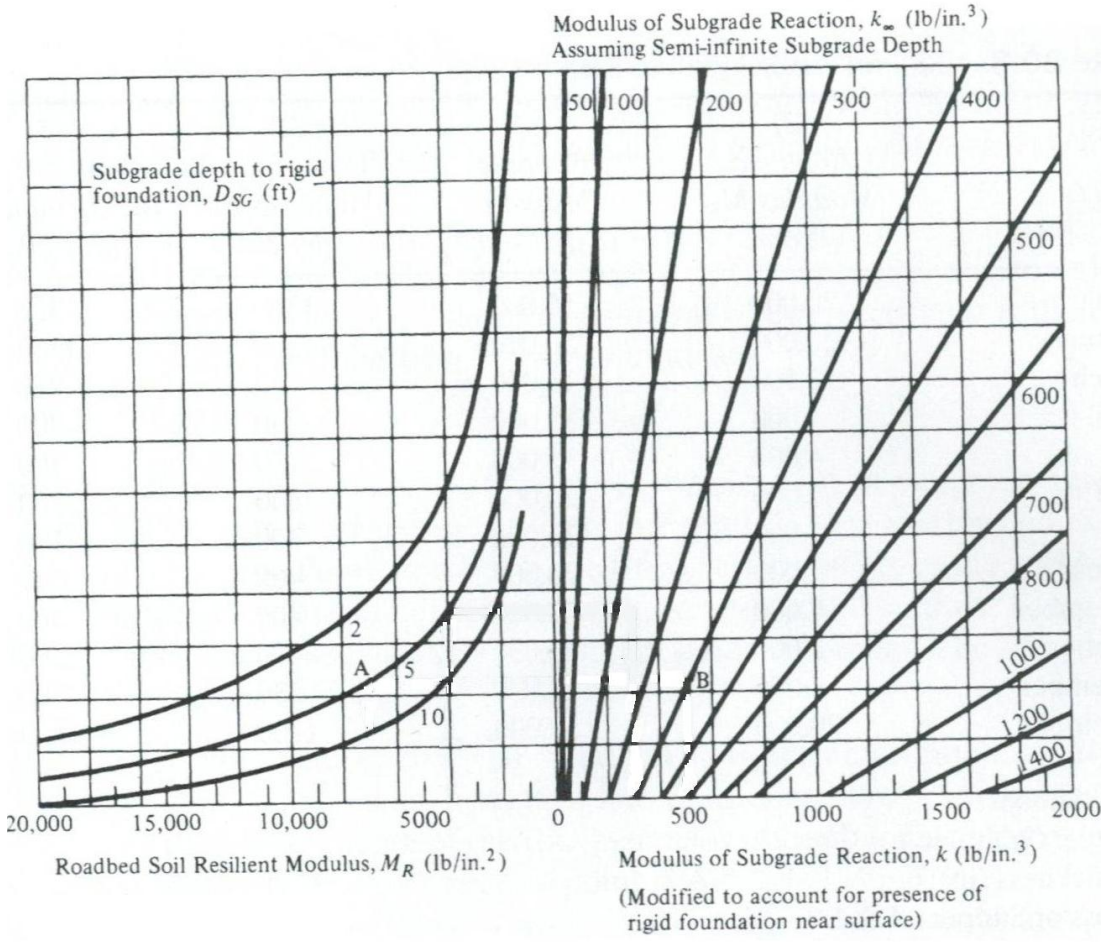
4. (4) What was the maximum safe speed for the curve under the present conditions, assuming the coefficient of friction and sight distance calculated above, and a reaction time of 2 seconds? Was Malone traveling too fast, or did something else happen?

Problem 4. (10 points). I search his car before the police arrive, and find a coded note. If I read it right, the Pigeon is buried nearby, 7 feet below the surface. However, the bedrock is pretty shallow, and I want to make sure it's more than 7 feet down before I start digging. I call my geologist friend – his name is Mr. Bogart, but I call him Mr. Flintstone because he can make my bedrock problems disappear. He digs up the second half of the rigid pavement nomograph used to design the roadway (see below) but can't find the first page. Other information he's given me include the drainage coefficient $C_d = 0.9$, the load transfer coefficient $J = 3$, the concrete modulus of rupture $S_c' = 550$ psi, and the concrete elastic modulus $E_c = 7 \times 10^6$ psi. It rains all year here, so the soil properties do not change from month to month. There's no loss of stability, and the soil analysis gives the soil resilient modulus to be M_R =10,000 psi and the modulus of subgrade reaction *ignoring bedrock* is $k_\infty = 300$ pounds per cubic inch. All necessary nomographs can be found below and on the next page.

1. (5) What was the *effective* modulus of subgrade reaction k?
2. (5) Is the bedrock more than 7 feet below the surface?




Concrete elastic modulus, E_c (10^6 lb/in.^{2})
7
6
5
4
3
800 500
100
50
10
Effective Modulus of Subgrade Reaction, k (lb/in.^{3})
T_L
Mean Concrete Modulus of Rupture, S'_c (lb/in.^{2})
1200
1100
1000
900
800
700
600
500
T_L
Load transfer coefficient, J
4.5
4.0
3.5
3.0
2.5
2.2
T_L
Drainage coefficient, C_d
1.3
1.1
0.9
0.7
0.6
Match Line
0
10
20
30
40
50
60
70
80
90
100


Modulus of Subgrade Reaction, k_∞ (lb/in.^{3})
Assuming Semi-infinite Subgrade Depth
Subgrade depth to rigid foundation, D_{SG} (ft)
50
100
200
300
400
500
600
700
800
1000
1200
1400
2
A
5
10
B
20,000
15,000
10,000
5000
0
500
1000
1500
2000
Roadbed Soil Resilient Modulus, M_R (lb/in.^{2})
Modulus of Subgrade Reaction, k (lb/in.^{3})
(Modified to account for presence of rigid foundation near surface)