The University of Iowa

Department of Civil & Environmental Engineering
CONSTRUCTION MATERIALS 53:130
Spring Semester 2001 Midterm Examination
Prof. C.C. Swan
Due Date: 2:30 pm, Monday, 26 March 2001

Question#1 (25 points)

The deck of a highway bridge crossing the Mississippi River between Iowa and Illinois is to be supported on a system of six-box girders fabricated of plate steel or plate aluminum. The box girders have outside cross-section dimensions of 1.50m x 1.50m', and are fabricated with 75.4mm plate. The cumulative length of each girder is to be 500m, and each girder will be simply supported by appropriately spaced concrete piers. The design life of the bridge is to be fifty years. Please consider the total lifetime cost of the following material alternatives and make a recommendation.

a. Usage of A36 steel which would need to be painted five times during the lifetime of the bridge (at 0, 10, 20, 30, and 40 years into its service life). The total cost of painting the bridge (crew mobilization, sandblasting, environmental impact minimization, and painting) is estimated to be $10 per square meter of painted area, and only the exposed external areas will be painted. The material cost of A36 steel is 0.15$ per pound.
b. Usage of A242 weathering steel (0.25 $ per pound), which would need to be treated at 20 years, and 40 years into its service life. The total treatment costs are still $10 per square meter.
c. Usage of A36 steel with hot-dip zinc galvanization. Assume that the hot-dip zinc galvanization adds 50% to the initial material cost of the steel. Further, assume that the bridge will need to be re-treated once during its lifetime (at 25 years) at a cost of $12 per square meter.
d. Usage of 6063 (T5) Aluminum alloy (1.40$ per pound), which would not require painting.

In making your cost comparisons, neglect inflation, assume an interest rate of 6%, and reduce all material-related expenditures to their present-worth as a basis for comparison.

Question#2: (25 points)

For Question #1, the factored static traffic loading on each girder will be 30 kN/m. Under both the traffic loading and the self-weight of each girder (with a load factor of 2.0), determine the maximum bridge pier spacing for each of the four material options considered. Assume that each girder will be simply supported on two bridge piers. Structural constraints to be considered are:

a. The maximum deflection in each span should be less than 0.025m.
b. The peak bending stress in each member should be no greater than 50% of the nominal yield stress.

Question #3: (10 points)

As part of the bridge construction project described in Questions 1 and 2, the supporting bridge piers are to be 30m tall and 7m in diameter.

a. Does the **size** of these bridge piers present any potential problem with respect to the quality (strength and stiffness) of the final cured concrete? If yes, please explain.
b. In terms of the curing process, possible admixtures, and the concrete mix design, what special steps might be taken in view of the **large size** of the bridge piers?

Question #4: (15 points)

a. Briefly, discuss the more common cement replacement materials in terms of: what they are; the benefits they yield; and in what proportions they are typically used.
b. What types of acids in the environment attack hcp, and what mix-design measures are the most effective in avoiding degradation from such acids? Briefly explain why each measure described should work.
c. For portland cement paste cured under dry conditions, with an original water-cement ratio of 0.43, calculate the capillary porosity, total porosity, and fraction of unhydrated cement. Show your work to receive credit.

Question #5: (25 points)

Perform a quantitative comparison of the characteristics of structural steel (A-36), structural aluminum (6063) and unreinforced concrete with respect to the following properties:

a. stiffness and specific stiffness;
b. strength and specific strength (tensile and compressive);
c. toughness;
d. ductility;
e. creep;
f. dimensional stability;
g. thermal conductivity;
h. fire resistance;
i. mass density;
j. initial cost;
k. lifecycle cost.