53:086 Civil Engineering Materials

Dept. of Civil & Environmental Engineering
The University of Iowa
Spring Semester 2006
Final Exam Version A

Question #1: (60 points)

Please answer the following questions in your exam booklet as either true or false. If you find the question to be worded ambiguously, you may provide a more extensive answer.

a) Asphalt and tar are two names that describe the same material.

b) Asphalt today is produced primarily as a residual product in petroleum refinement.

c) One of the primary reasons that asphalt concrete is not used as a structural material in civil engineering structures is that it costs about twice as much per ton as portland cement concrete.

d) Tar is soluble in most refined petroleum products.

e) It can be potentially unsafe to work with asphalt binders at temperatures at or above the flash point.

f) In HMA mix design, it is desirable to have a target VTM of 0% although this can rarely be achieved in practice and so values of up to 4% are accepted.

g) A reasonable value for the VFA in a compacted HMA pavement is about 70%.

h) A VMA value of 10-14% in compacted HMA pavement is typically quite reasonable.

i) In HMA it is typically most desirable to use a well-graded, rounded aggregate with an absolute minimum of crushed particles.

j) A performance grade asphalt binder with the designation PG 70-40 would be suitable in a region where the high design temperature for a pavement is 70ºC and the low design temperature is -40ºC.

k) In emulsions, asphalt binder is combined with more volatile phases of petroleum that will eventually evaporate away, leaving the asphalt binder behind.

l) A typical mixing temperature for HMA is about 77ºC or 170ºF.

m) Some age hardening of asphalt cement will occur during the HMA mixing process and this can be simulated with the RTFO and TFO procedures.

n) A characteristic of viscoelastic materials like asphalts is that they are sometimes very compliant when loaded slowly and comparatively stiff when loaded rapidly.

o) As asphalt cement ages, it tends to become increasingly fluid and this will lead to increasing problems with rutting and bleeding of a pavement.

p) The aging that occurs during 5-10 years or service life is usually simulated with the Precision Asphalt Volumetric (PAV) test.

q) Thermoplastic polymers are often used in structural FRPs due to their higher temperature resistance than thermoset polymers.

r) In structural FRPs, the polymer matrix tends to provide most of the composite stiffness and strength, and the fibers are a low-cost filler item to keep the overall cost down.

s) Two common "mixing rules" used to estimate the stiffness and strength properties of fibrous composites are the Voigt iso-strain rule and the Reuss iso-stress rule. It is appropriate to use the Voigt iso-strain rule when considering loading parallel to aligned fibers, and to use the Reuss iso-stress rule when considering loading transverse to aligned fibers.

t) Common structural polymers used in FRPs are generally stiffer than steel.

u) Common structural fibers used in FRPs (glass, graphite, Kevlar) are actually stronger than A-36 structural steel.

v) Although many structural composites have unit weights comparable to those of structural steel, they tend to be much stronger than most grades of steel. This is why FRPs often have high strength to weight ratio compared to structural steel.

w) In masonry, "units" is a term that represents the bricks, blocks, or stones that are arranged to form the structural system.

x) Hollow cells or holes are often incorporated in both clay and concrete units to make them more thermally resistive (better insulators).

y) Concrete masonry units are generally made in factory conditions with drier pcc mixes than are used in typical cast-in-place concrete applications.

z) Because concrete masonry units are made with such dry mixes, they tend to expand over time, unlike cast-in-place concrete that tend to shrink over time due to loss of moisture to the atmosphere.

aa) Clay bricks, although they undergo a firing process, retain some of the characteristics of clay soils to suck in moisture and to gradually expand over time.

bb) The primary difference between clay bricks that can be used in weathering conditions and those that can be used only for interior-non-weathering applications relates to their moisture absorption characteristics. Bricks that have the capacity to absorb more moisture can be used in weathering conditions. Those with low absorption capacity must be used strictly in non-weathering applications.

cc) Efflorescence of masonry is the appearance of a whitish carbonate deposit on the exterior wall faces and is usually indicative of inadequate control of moisture getting into the wall and drainage.

dd) Cavity walls involve single-wythe construction with hollow units.

Question #2: (10 points)

An aggregate blend is composed of 53% coarse aggregate by weight (G_s=2.702), 43% fine aggregate (G_s=2.621), and 4% filler (G_s=2.779). The compacted specimen contains 6% asphalt binder (G_b=1.052) by total weight of the mix and has a bulk density of 145.2 lb/ft^3. Ignoring absorption, compute:

a. the maximum theoretical specific gravity of the mix, G_{mm};
b. the bulk specific gravity of the mix, G_{mb};
c. the percent voids in the total mix (VTM);
d. the percent voids in the mineral aggregate (VMA); and
e. the percent voids filled with asphalt (VFA).

Question #3: (20 points)

An asphalt binder has a shear modulus G= 4 MPa, a viscosity η=20 MPa·s and its constitutive behavior is governed by the following differential equation: $\tau = G\gamma + \eta\dot{\gamma}$. Assume that the binder is subjected to an oscillatory strain-controlled dynamic shear-rheometer test as follows: $\gamma = \gamma_0 e^{i\omega t}$ where the strain amplitude $\gamma_0 = 0.01$. For a loading frequency of $\omega = 10 rad \cdot s^{-1}$, calculate the amplitude of the resulting shear stress, and the phase angle between the shear stress and strain. (Assuming that $\tau = \tau_0 e^{i(\omega t+\delta)}$, compute τ_0 and δ).

Question #4: (10 points)

A composite is made with long, aligned graphite fibers having E=241 GPa and a polyester matrix with E=4 GPa. The fiber volume fraction in the composite is 60%. Calculate:

a. the effective Young's modulus in the fiber direction;
b. the effective Young's modulus in the transverse direction;