NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2009-2010

CV2003 – CIVIL ENGINEERING MATERIALS

April – May 2010 **Time Allowed: 2½ hours**

INSTRUCTIONS

1. This paper contains **FOUR (4)** questions and comprises **FOUR (4)** pages.
2. Answer **ALL FOUR (4)** questions.
3. All questions carry equal marks.

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1. (a) Write short notes on the following commonly-used grading systems for asphalt cement binder:
   - penetration grading system;
   - performance-based grading system.

   Comment on the merits of each system.

   (8 marks)

   (b) Explain what is aggregate bulk density, and aggregate effective density, as applied in an asphalt concrete.

   Discuss why knowledge of aggregate density is important for asphalt concrete mix design.

   (7 marks)

   (c) A dense-graded asphalt concrete Marshall specimen was made using 1,200 g aggregate and 70 g binder, and the specimen weighed 735 g when suspended in water. It is known that this type of mix has a theoretical maximum density of 2.430 g/cm^3. The void in total mix (VTM) is to be determined for the specimen.

   (i) Show that VTM of the specimen is related to its bulk density (d) and the theoretical maximum density (D) by a relationship of the form:

   $$VTM = (D-d) / D$$

   (ii) Determine the VTM value and comment on the suitability of this mix, given the applicable specification limits of $3\% \leq VTM \leq 5\%$.

   (iii) If the VTM value is outside the specification limits, which aspects of mix design could have contributed to the non-compliance?

   (10 marks)

2. (a) With the aid of Fe-C phase diagram, describe the evolution of the microstructure of hypo-eutectoid steel during cooling from the A_3 upper critical temperature.

(5 marks)

(b) Describe the influence of increasing cementite and pearlite contents on the following engineering properties of steel:

(i) Hardness
(ii) Yield strength
(iii) Ductility
(iv) Toughness

(5 marks)

(c) During welding, a temperature gradient is established. The temperature varies from the fusion temperature at the weld metal to room temperature at the parent metal away from the weld. Describe the change in the microstructure and properties in terms of strength and ductility in the heat-affected zone across the weld in low carbon steel.

(5 marks)

(d) In the case of timber, the structural properties are dependent on the orientation of its grain structure whereas this is not the case for steel. Explain why.

(5 marks)

(e) Explain the meaning of timber 'seasoning' and 'preservation', and why it is necessary to carry out both processes for some species of timber.

(5 marks)

3. (a) A sieve analysis of a fine aggregate (sand) gives the following results:

Sieve size (mm)	9.50	4.75	2.36	1.18	0.6	0.3	0.15	Pan
Mass retained (g)	0	15	55	100	115	135	70	10

(i) Determine the % retained and the cumulative % retained for each sieve size.

(ii) Determine the fineness modulus of the fine aggregate.

(iii) What is the average size of the fine aggregate?

(iv) Determine the percentage of the fine aggregate passing the 600 μm sieve.

(v) Is this a well graded or uniformly graded fine aggregate? Briefly explain why.

(15 marks)

(b) Describe the four moisture states of aggregates: oven-dry, air-dry, saturated-surface-dry and wet. How does the moisture state of aggregates affect the concrete mix design?

(10 marks)

4. (a) Briefly explain how the following factors influence the workability of concrete:

(i) Aggregate size.
(ii) Air-entrainment agents.

(6 marks)

(b) Briefly discuss the followings:

(i) What are the differences between the shrinkage and the creep in concrete?

(ii) What are the effects of aggregate content on the creep/shrinkage of concrete?

(iii) In the concrete mix design, why the concrete with the crushed aggregates is assumed to have a higher strength than the concrete with the uncrushed aggregates?

(iv) What is the main purpose of adding the set-retarder (a chemical admixture) into the concrete?

(12 marks)

(c) Briefly describe the main features of the following special concrete:

(i) High strength concrete.
(ii) Fiber reinforced concrete.

(7 marks)

END OF PAPER

CV2003 Semester 2 2009-2010

1. (a) Penetration grading system

Measures the hardness of a bituminous material at 25° C
Higher values imply softer asphalts.

The test temperature is low, thus the energy required is low.

Performance-based grading system
Developed by SHRP, marketed as Superpave
Specification based on high and low temperatures
High temperature: 46-82° C, by 6° step; low temperature: -10- -46° C, by 6° C step

The testing, design and evaluation procedures more closely simulate actual loading and climatic conditions.

(b) Bulk density- ratio of mass of aggregate over volume that includes all surface voids
Effective density- ratio of mass of aggregate over volume that excludes all surface voids permeable to asphalt

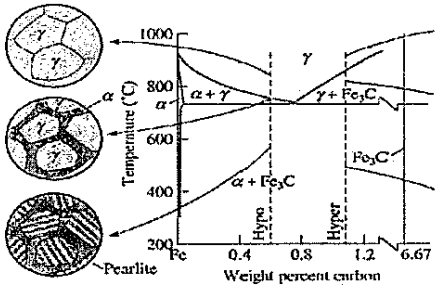
Manufacture of asphalt concrete is based on weight measure, while control of mix is based on volumetric properties. Therefore, knowledge of density which equals mass over volume is required for mix design calculation.

(c) (i) $VTM=\frac{V_A}{V}=\frac{V-V_{MM}}{V}=1-\frac{V_{MM}}{V}=1-\frac{d}{D}=\frac{D-d}{D}$

(ii) V= (1200+70-735)/1=535 cm^3
D= (1200+70)/535=2.374g/cm^3
VTM= (2.430-2.374)/2.430=2.3%<3%
Not applicable

(iii) The binder content is too high, thus more air voids are filled up.

2. (a)



(b) Increasing cementite and pearlite

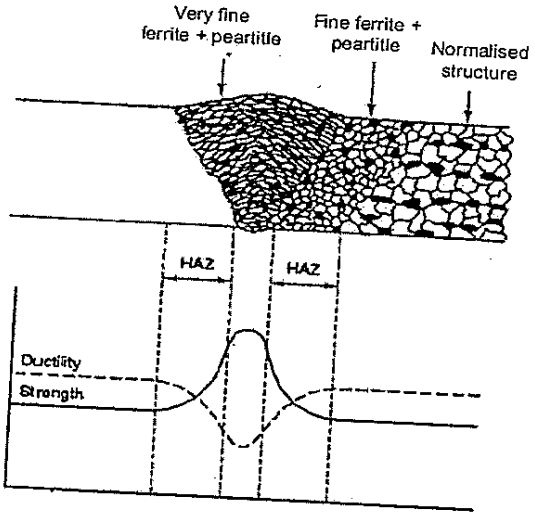
Hardness will increase

Yield strength will increase

Ductility will decrease

Toughness will decrease

(c)



(d) The variation of structural properties between different directions can be attributed to the anisotropic structure of the wood cells.

In the longitudinal direction, the covalent bonds of cellulose microfibrils determine the behaviour. In the transverse direction, it is determined by the hydrogen and VDW bonds.

While steel is an isotropic material thus the structural properties do not vary with the orientation of its grain structure.

(e) Seasoning: timbers should be seasoned by natural or kiln-drying means to a moisture content appropriate to the position in which it is to be used.

Preservation: treat the timber using tar oils, water borne preservations or organic solvent preservations to increase its durability.

For some species of timber, they must first be seasoned below the fibre saturation point before preservative treatment.

3. (a)

(i) Total weight= 500g

Sieve size	Weight retained	% retained	Cumulative % retained
9.50	0	0	0
4.75	15	3	3
2.36	55	11	14
1.18	100	20	34
0.6	115	23	57
0.3	135	27	84
0.15	70	14	98
pan	10	2	100

(ii) FM= (3+14+34+57+84+98)/100=2.9

(iii) Ave size= $\sum$ size $*$ % retained $= 0.88\text{mm}$

(iv) 27%+14%+2%=43%

(v) well graded Has a good mix of all particles sizes which means the aggregate use most of the volume and less cement is needed

(b) Oven-dry: all moisture is removed from the aggregate by heating in an oven at 105°C to constant weight. All pores are empty.

Air-dry: All moisture is removed from the surface of the aggregate particles, but the internal pores are partially full

Saturated-surface-dry: All of the aggregate pores are filled with water. But there is no film of water on the surface of the particles.

Wet: All of the aggregate pores are completely filled with water and there is a film of water on the surface of all of the particles.

The surface water on the aggregates is available for the hydration of cement so that the mass of this water should be taken into consideratin in the mixing design for the water content determination.

4. (a) Aggregate size: larger the aggregate, less the specific surface area, thus less water required for lubrication. Therefore, the workability is higher.

Air-entrainment agents: improve workability by increasing flow properties and reducing segregation.

(b) (i) shrinkage: the driving forces for water movement are environmental conditions causing diffusion of water outward.
Creep: the driving force is stress, which causes water to move from one location to the other within the concrete.

(ii) Volume change mainly occurs inside the cement paste c.p., so higher the aggregate content, lower the creep and shrinkage.

(iii) Crushed aggregate has a rougher surface and more angular shape than the uncrushed aggregate, resulting a stronger bond between the aggregate ~~than~~ and mortar.

(iv) To delay the setting of the concrete by slowing down the early hydration reaction.

(c) (i) High strength concrete:
The higher the strength the more brittle the concrete;
The modulus elasticity does not increase at the same rate of as strength;
Utilization of higher working stresses in high-strength concrete leads to higher deformations than in normal-strength concrete

(ii) Fibre-reinforced concrete:
Increase the tensile strength by delaying the growth of cracks, and to increase the toughness by transmitting stress across a cracked section to that much larger deformation is possible beyond the peak stress than without fibre reinforcement;
Workability decreases as the fibre content increases and as the aspect ratio increases;