NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2008-2009

CV2003 – Civil Engineering Materials

November 2008 **Time Allowed: 2½ hours**

INSTRUCTIONS

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

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1. (a) Describe the microstructural changes of hypo-eutectoid and hyper-eutectoid steels as each is cooled from the molten state to room temperature condition.

(8 marks)

(b) List and explain ways that structural steel can be strengthened.

(5 marks)

(c) What is a fibre saturation point (FSP)? Hence, explain how moisture content in timber affects the strength of timber.

(4 marks)

(d) What are the advantages and disadvantages of using polymer as civil engineering material?

(8 marks)

2. (a) Why is concrete the most widely used construction material? Explain the disadvantages of concrete as a construction material.

(5 marks)

(b) What type of Portland cement according to the ASTM classification would you use in each of the following cases? For each case, indicate the reason for your choice.

(i) Construction in cold weather
(ii) Building foundation in a soil with severe sulfate exposure
(iii) Construction of a massive dam
(iv) Construction in hot weather
(v) Concrete structure without any specific exposure condition

(10 marks)

(c) Explain the advantages and disadvantages of using larger maximum size of aggregate in concrete.

(5 marks)

(d) Give three reasons for adding a superplasticizer in a concrete mixture.

(5 marks)

3. (a) Name three mineral admixtures commonly used in concrete, with brief explanations to highlight their uses. Which of these mineral admixtures usually has angular shape?

(7 marks)

(b) Explain how chloride penetration allows the initiation of the corrosion of steel in concrete. What strategies can be used to minimize the chloride-induced corrosion of steel in concrete?

(8 marks)

(c) What is Self-Compacting Concrete? What are the advantages of using Self-Compacting Concrete?

(6 marks)

(d) Two concretes, A and B, made from the same mix design and materials, are cured in the field. It is determined that it is safe to strip the formwork from concrete A after 7 days moist curing at 25°C. If concrete B is first cured for 3 days at 15°C, how many additional days must it be cured at 25°C before the formwork can be stripped?

(4 marks)

4. (a) With the aid of a sketch, indicate the constituent layers of a flexible pavement.

List three important physical properties of a mineral aggregate used in the binder course of an asphalt concrete pavement. Briefly explain why you consider them important.

(8 marks)

(b) Write short notes on three important physical properties of asphalt cement that is used as a binder in asphalt concrete.

Indicate how binder content and binder stiffness affect structural stiffness, deformation resistance, and workability of the asphalt concrete mix.

(9 marks)

(c) Explain what are stability and flow as measured in the Marshall Test.

An asphalt concrete Marshall specimen was fabricated using 1,200 grams of granite aggregate (with bulk relative density of 2.60) and 60 grams of binder (with relative density of 1.03). The Marshall specimen weighed 686 grams when suspended in water. Determine, for this specimen, the voids in total mix (VTM). Assume that binder absorption is 1.0% of aggregate mass.

Comment on the VTM value for this mix.

(8 marks)

END OF PAPER

(set 1)

CV2003 CIVIL ENGINEERING MATERIALS (SEMESTER 1 08/09)

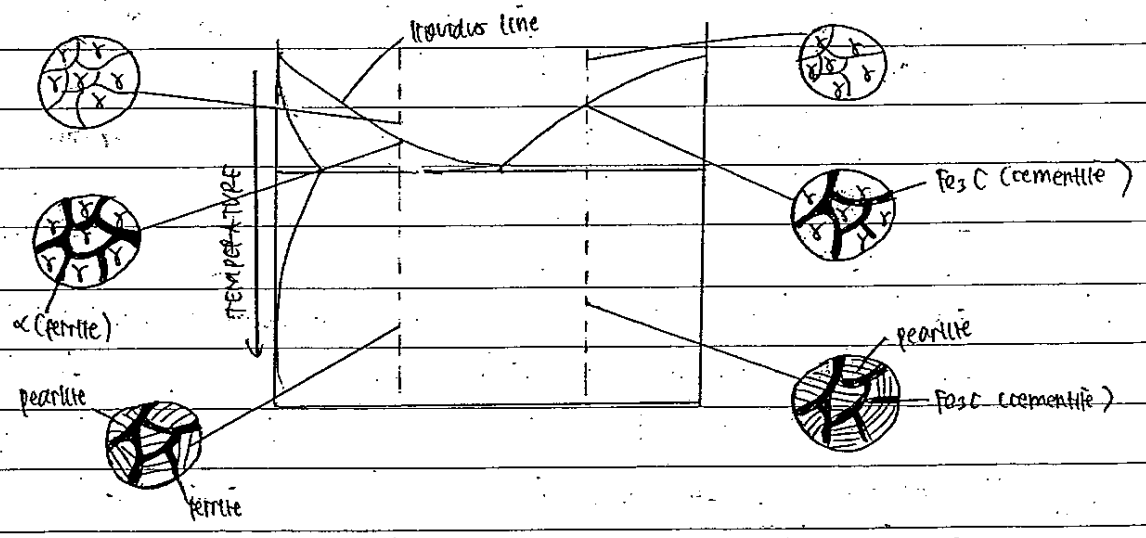
1

a. Hypoeutectoid:

In the molten state, the microstructure consists of 100% austenite (γ). As temperature drops and meets liquidus line, ferrite (α) phase will form; the microstructure now consists of α and γ phase (ferrite and austenite phase). As temperature drops further, austenite turns into lamellae of pearlite, and thus making the microstructure of hypoeutectoid steel becomes α-phase and pearlite structure.

Hypereutectoid:

In the molten state, the microstructure consists of 100% austenite (γ), as temperature drops and meets liquidus line, cementite (Fe_3C) will form; the microstructure now consists of γ + Fe_3C phase (austenite + cementite phase). As temperature drops further, the austenite turns into lamellae of pearlite, and thus making the microstructure of hypereutectoid steel becomes cementite and pearlite phase.



b. 1/ introduction of interstitial and substitutional atoms (alloying)

2/ the generation and concentration of dislocations (work or strain hardening)

3/ the formation of additional grain boundaries (heat treatment)

c. Fibre saturation point (FSP): moisture content at which the cell wall is saturated with bound water and at which no free water is present.

the effect of moisture content to strength of timber:

↑ moisture content ↓ strength

However, if the timber has exceeded the fibre saturation point, addition and removal of water has almost no effect on the timber strength and any wood properties.

d. Polymer:

advantages:

- low density (lightweight)
- low thermal conductivity (as insulation at room temperature)
- easily moulded/shaped
- good resistance to chemicals and not subject to chemical corrosion

disadvantages:

- low modulus, hence not suitable for use as structural material
- higher thermal expansion than other materials
- poor resistance to heat
- degradation due to ultraviolet

2

a. concrete is widely used as construction material because it is relatively cheap while at the same time, durable and considerably strong for use as construction material.

disadvantages of concrete:

- low tensile strength, concrete is only good in compression
- low ductility, concrete is brittle and doesn't show sign. prior to failure
- volume instability, shrinkage of concrete often happens
- low strength to weight ratio

b. (I) Type III cement. In cold weather, we need the concrete to hydrate fast enough and finish the chemical reaction before it is frozen and therefore, type III cement is used, as rapid strength gain allows concrete to harden faster and faster chemical reaction.

(II) Type V cement. Type V cement contains very low C_3A composition, which accounts for its high sulfate resistance

(III) Type IV cement. Type IV cement develops strength slowly, but for the long run, the strength is higher than other types after full curing. For dams which have low surface to volume ratio, type IV is generally used.

(IV) type II cement. In hot weather, higher initial curing temperature will result in rapid strength gain, but lower ultimate strength. cement with considerably low heat hydration can be used to prevent the rapid strength gain.

c. advantages:

- reduce cement content for specified workability
- reduce total heat of hydration, for specified workability
- reduce water/cement ratio for specified workability

disadvantages:

- for a particular volume of aggregate, compressive strength decrease as the size

of concrete increase.

- Increase stress concentration in mortar - aggregate interface

d. - produce high strength concrete - normal workability but low w/c ratio

- increase slump and flow - for placing of concrete in inaccesible location, or for rapid placing

- reduce water/cement ratio

a. mineral admixtures : slag, fly ash, and silica fume

angular shape ⇒ slag

slag : increase strength of concrete over longer period, reduce permeability, increase durability

fly ash : increase compressive strength of concrete

silica fume: lower bleeding rate of concrete, and decrease water permeability of concrete

b. Penetration of chlorides into concrete causes depassivation (damage of thin protective film of iron oxide on the metal surface of steel reinforcement) - Depassivation occurs when the chloride ion content reaches a value in the range of 0.2% to 0.4% by weight of portland cement in the concrete adjacent to steel. Depassivation makes the steel vulnerable to steel, and will lead to corrotion.

to minimize chloride induced corrosion of steel:

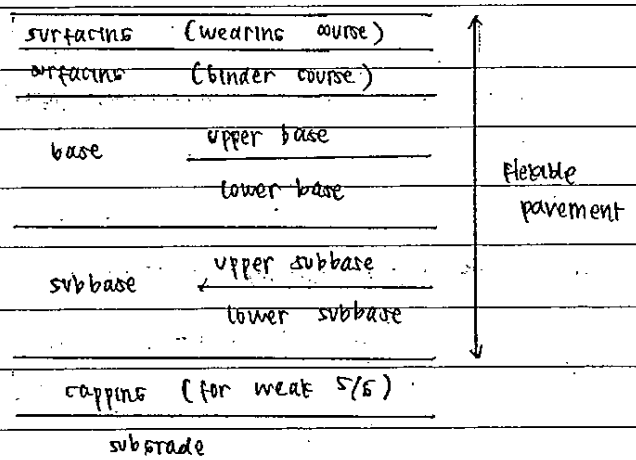
- use longer curing period
- lower w/c ratio to decrease water permeability to concrete
- use type V of portland cement
- addition of fume, fly ash, or slag

c. self compacting concrete is a kind of concrete with high flowability and high resistance to segregation

advantages :

- high dispersability
- high early strength and high flowability → increase productivity
- better surface texture
- reduce noise due to vibration
- high resistance to segregation
- less manpower

[4] a.



physical properties of mineral aggregate :

- toughness : to provide resistance against abration and degradation during manufacture, construction, and in-service
- soundness : to be free from planes of weakness for better resistance to breakdown due to

freezing and thawing

- surface texture : preferable to have rough texture to provide stiffer mix, better asphalt affinity, more skid resistance.

b. physical properties of asphalt cement :

1/ workability

is important for the ease of placement and compaction. It depends on composition of aggregates and temperature. Too much of coarse aggregate and filler will make it difficult to compact. High temperature of compaction increases workability.

2/ skid resistance

Asphalt concrete must be able to provide skid resistance under all environmental conditions. Wearing course requires smaller sized and hard aggregate.

3/ deformation resistance

asphalt concrete should have good resistance to excessive deformation under load. Deformation can be in the form of rutting (densification of mix) or lateral movement.

↑ binder content ↑ workability ↓ structural stiffness ↓ deformation resistance

c. stability = maximum load applied to reach maximum deformation

flow : maximum deformation as the result of applied loading

M_B (mass of aggregate) = 1200 g — M_B (mass of binder) : 60 g

ρ_B = 2.6 g/cm³ — ρ_B = 1.03 g/cm³

weight in water : 686 g — binder absorption = 1%

Bulk Volume (V) = $\frac{\text{weight of specimen in air} - \text{weight of specimen in water}}{\text{density of water}}$

$= \frac{(1200+60) - 686}{1} = 574\ cm^3$

d : bulk density : $\frac{\text{mass of specimen}}{\text{bulk volume}} = \frac{(1200+60)}{574} = 2.195\ g/cm^3$

volume of aggregate (V_G) = $M_G/\rho_G = 1200/2.6 = 461.5385\ cm^3$

Mass of absorbed binder (M_{BA}) = Mass of aggregate × percentage of absorption

$= 1200 \times 1\% = 12\ g$

Mass of effective binder (M_{BE}) : mass of binder - mass of absorbed binder

$= 60 - 12 = 48\ g$

Volume of effective binder (V_{BE}) : $M_{BE}/\rho_B = 48/1.03 = 46.602\ cm^3$

Volume of void-less mix (V_{MM}) = $V_{BE} + V_G$

$= 46.602 + 461.5385 = 508.1405\ cm^3$

Max. theoretical density (D) : $M/V_{MM} = (1200+60)/508.1405 = 2.48\ g/cm^3$

$VTM = \frac{D-d}{D} = \frac{2.48 - 2.195}{2.48} = 11.47\%$

VTM is too high, it exceeds the limit of $3\% \leq VTM \leq 5\%$.

- THE END -

GOODLUCK =)

(set 2)

CV 2003
Nov '08 Sem 1

1(a)

If a hypoeutectoid steel is cooled from the γ-region, as soon as the temperature hits the transformation curve, α-ferrite will form along the austenite grain boundaries. When temperature goes lower, the α and γ are in equilibrium. The compositions are related by the temperature tie-line. As the temperature is decreased, the last austenite will attain the eutectoid composition that transforms to pearlite at the eutectoid temperature.

If a hypereutectoid compostition is cooled from the γ-region, the first phase to form this time is cementite, which is the proeutectoid phase. As the steel cools further, more cementite with constant composition at 6.69%C will form. At the eutectoid temperature, the remaining γ will transform to pearlite.

1(b)

Strain hardening and recrystallisation

Recrystallization is a process in which new strain-free grains are created and grow.
Strainhardening is plastic deformation below there crystallization temperature where resistance to further deformation increases with increasing amounts of deformation.

example: cold working

Heat treatment

Full-annealing
To put a hypo-eutectoid steel into the softest possible condition.

Normalising
The faster rate of cooling gives a finer pearlite structure and the steel, while relatively soft and ductile, is finer pearlite structure and the steel, while relatively soft and ductile, is
some what harder than full annealed material.

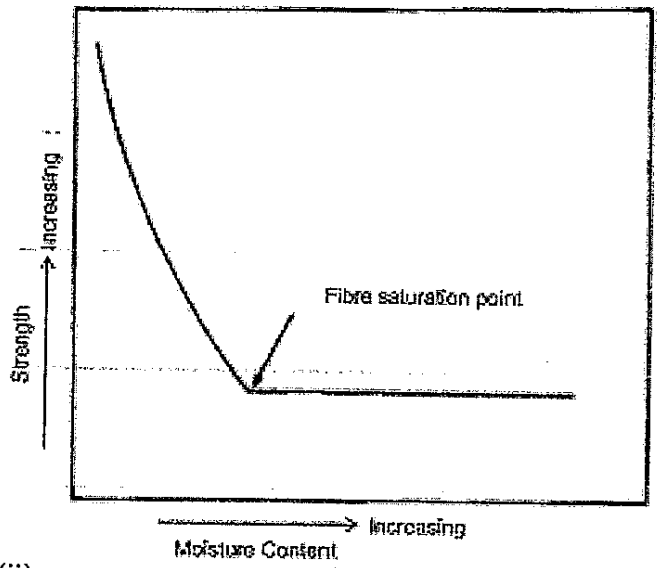
Spheroidise annealing
These steels can be softened by heating the at a temperature just below the critical temperature. During this treatment the cementite reforms into small spheroidal shaped particles, and this greatly toughens the material.

Processannealing or subcritical
A process often used for softening cold worked low carbon steels.

Hardening
A steel is hardened by rapidly quenching the steel, from a high temperature, into
water or oil. The very rapid cooling through the critical temperatures causes the
formation of martensite.

Tempering
Hardened steels may be tempered by heating within the range 200-700°C. This treatment will remove internal stresses created by quenching, reduce the hardness, and increase the toughness of the steel and increase the toughness of the steel.

1(c)
(i)
Themoisturecontent at whichthe cell wall is saturatedwith bound water &at whichnofreewater is present is called the fibresaturation point, (FSP)



(ii)
Addition or removal of water below the FSP has a pronouncedeffect onpracticallyall woodproperties.

Additionor removal of water above theFSPhasalmost noeffect on Anywoodproperties.

1(d)

Advantages

Lightweight
Low thermal conductivity
Easily moulded/shaped
Good resistance to chemicals and not subject to electrochemical corrosion

Disadvantages

Unsuitable for use as structural materials.
Higher thermal expansion than other material
Degradation due to ultra-violet light is common. It can result in brittleness, increased opacity of a transparent material, loss in strength, cracking, etc.

2(a)

Concrete is used more than any other man-made material in the world, because It has the following *advantages*.

Durability, Strength, Low Maintenance
Ability to cast
Economical
Energy saving
Fire Resistance
On-site Fabrication
Aesthetic Value

Disadvantages

Low tensile strength
low ductility
Volume instability
Low strength-weight ratio

2(b)

(i)Type III, concrete in to be casted at low temperature.
(ii)Type V, concrete is exposed to sulfate attack.
(iii)Type IV, used for large concrete construction
(iv) Type II, low heat generation is desirable and sulphate attack may occur.
(v)Type I, general concrete construction.

2(c)

Using larger maximum size of aggregate

advantages:
reduce the cement content
reduce the total heat of hydration
reduce water/cement ratio, for specified workability.

disadvantages:
with the increase in the size of the coarse aggregate, the compressive strength decreases.

The stress concentration in the mortar-aggregate interface increases with the maximun size of the aggregate.

2(d)

(i)produces a low water/cement ratio giving high performance concrete.
(ii)while providing superior workability, concrete can achieve high strengths

3(a)

FLY ASH

Fly ash is frequently used in mass concrete as a cement replacement to reduce the heat of hydration, which in turn reduces peak temperatures, temperature gradients, and the likelihood of thermal cracking.

SILICA FUME

the use of silica fume will reduce the permeability of the concrete, thereby slowing the rate of penetration of aggressive chemicals

GROUND GRANULATED BLAST-FURNACE SLAG(*angular*)

The use of slag lowers concrete permeability, thereby reducing the rate of chloride ion diffusion.
For alkali-silica reaction, slag consumes some of the alkalis produced from the portland cement leaving them unavailable for reaction with the aggregates. Proper proportioning of slag cement can eliminate the need to use low alkali or sulfate-resistant portland cements.

3(b)

The strongly alkaline nature of calcium hydroxide prevents the corrosion of the steel reinforcement by the formation of a thin protective film of iron oxide on the metal surface. However, the penetration of chlorides into the concrete enables the depassivation to occur when the chloride ion content reaches the range of 0.2% to 0.4% by weight of the cement.

protection strategy:
Avoid using chloride based admixtures
Pozzolan addition, slag addition
Proper cover
Lower water/cement ration and sufficient cement
Sufficient curing time
Denser concrete

3(c)
Self compacting concrete is a kind of concrete with high flowability and high resistance to segregation

Advantages:
high dispensability
high early strength
highflowability
better surface texture
reduce the noise due to vibration
high resistance to segregation
less manpower

3(d)

$7*25 = 3*15+X*25$

$X=5.2$ days

4(c)
(i)

The Marshall stability and flow test provides the performance prediction measure for the Marshall mix design method.

The stability portion of the test measures the maximum load supported by the test specimen. Basically, the load is increased until it reaches a maximum then when the load just begins to decrease, the loading is stopped and the maximum load is recorded.

During the loading, an attached dial gauge measures the specimen's plastic flow as a result of the loading. The flow value is recorded at the same time the maximum load is recorded.

(ii)

Bulk Volume of Agg	V_{agg}=1200/2.60	=461.54 cm^3
Volume of Binder	V_{Binder}=60/1.03	=58.25 cm^3
Volume of effective binder	V_{BE}=48/1.03	=46.60 cm^3
Volume of specimen	V=(W_a-W_w)/ρ_w	=574.0 cm^3
Volume of Air	V_{air}=V-V_{agg}-V_{BE}	=65.86 cm^3
VTM	V_{air}/V	~~=1.147%~~ 11.47%