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CV 1013 2012-2013 Solution Date No.

1. (a) (i) ① Asphaltenes. It is hard and provides strength and stiffness.

② Resins. Provides ductility and adhesiveness.

③ Oils. Contributes viscosity and fluidity and gives workability.

(ii) Each asphalt exhibit a different temperature susceptibility. Viscosity of asphalt changes with temperature. The important consideration in hot climate is rutting problem, which means materials become softer and lead to deformation. In cold weather, the consideration is cracking problem. This is because viscosity decreases with increasing of temperature.

(b) Functions of aggregate particles in HMA is to provide stability to mix by interlock and also provide a rough surface texture with good skid resistance. Angular aggregates can provide better interlock and stability by its shape. Rough texture can provide stiffer mix, better asphalt and more skid-resistant asphalt mix. Hence, angular and rough are preferred

(c) Stability is the Max force under compaction.

Flow is the strain at max force.

Total volume $V = (W_a - W_w)/\rho_w = (1200+80-680)/1 = 600\ cm^3$

Volume of aggregate $V_G = 1200/2.4 = 500\ cm^3$

Volume of binder $V_B = 80/1.05 = 76.19\ cm^3$

Volume of absorbed asphalt $V_{BA} = M_{BA}/\rho_B = 3.0\% \times 1200/1.05 = 34.29\ cm^3$

Volume of voids $V_A = V - V_G - V_{BE} = V - V_G - V_B + V_{BA}$

$= 600 - 500 - 76.19 + 34.29 = 58.1\ cm^3$

$VTM = 100\ V_A/V\ (\%) = 100 \times 58.1/600 (\%) = 9.68\%$

Properly designed, a HMA mix should have an air-void content of 3%-5%. Apparently, 9.68% is much higher. And this will decrease the strength and stability of asphalt concrete. Also the amount of moisture will increase and decrease the durability.

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2. (a) ① Alloyed steel: the introduction of interstitial and substitutional atoms. Interstitial can pack space between atoms so that they cannot move easily. Substitution can replace atoms missing, which can impede the motion of dislocations.

② Cold-worked steel: generation and concentration of dislocations. Dislocations concentrate at grain boundary, which makes boundary stronger.

③ Heat-treated steel: the formation of additional grain boundaries. Heat it up quickly and fast cooling will generate more grain boundaries, which can prevent deformation well.

(b) ① The strength of steel refers to the maximum amount of tensile stress that it takes before failure.

Measurement: take a small sample with a fixed cross-section area and then pull it, gradually increasing force until it breaks.

Strength is important because it determines how much the steel can load without failure. Also it is important for safty consideration.

② Ductility is the ability to deform under tensile stress.

Ductility can be measured by fracture strain at which the sample fractures during a uniaxial tensile test.

It is important as proper ductility of steel may prevent failure. Some metals are high ductile with considerable plastic deformation before failure (Failure by yielding). If the steel has very low ductility which means it is very brittle.

③ Toughness, a measure of the ability of a material to absorb energy prior to failure, and it can been evaluated by: Area under stress-strain diagram, impact test (charpy V-notch test), and Fracture mechanics approach.

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It is important for steels that suffer impact. Increase strength usually lead to decreased toughness. It measures the resistance to failure — fracture

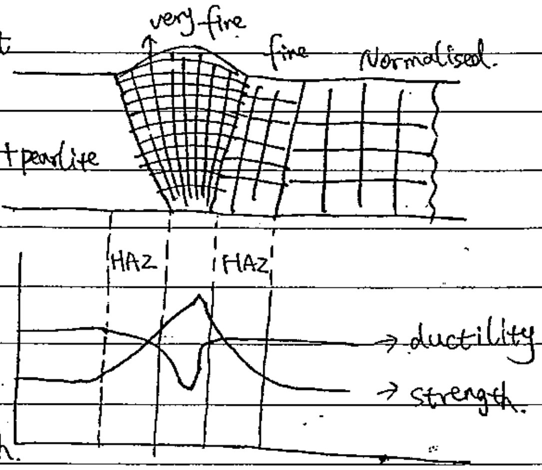
④ Weldability is the capacity of a metal to be joined by welding into a structure that can perform in a satisfactory manner for an intended service.
Measurement: It decreases as the carbon and alloy content of steel is increased.

$$CE = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$$

. Lower CE, more weldable.

Welding is important for the production of complex shape and has strong influence on fatigue strength. Higher weldability means the steel is easy to be welded to produce other shapes.

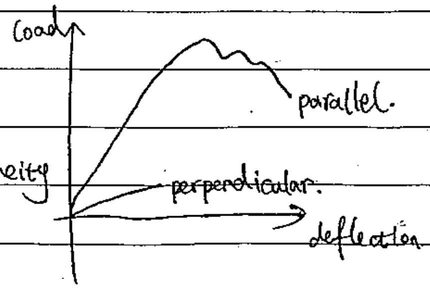
(c) From the diagram, it is obvious that the change of microstructure is very fine ferrite + pearlite → fine ferrite + pearlite → normalised structure.



The strength is decreased at first and then increased.
The ductility is increased at first and then decreased as shown in the graph.
Use heat treatment to remedy the situation.

(d) (ii) The orientation of cellulose fibrils and tubular holes and the spatial gradation of porosity leads to anisotropy and in-homogeneity of the macroscopic material behavior.
In longitudinal direction, the covalent bond of cellulose microfibrils determines the behavior.
In the transverse direction, it is determined by hydrogen and Van der Waals bonds.

(i)



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3. (a) Initial set: paste is beginning to stiffen considerably and can no longer be molded. Generally occurs in 2 to 4 hours.

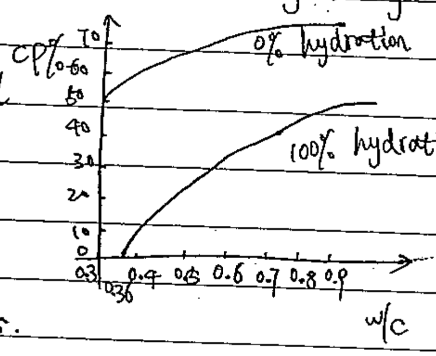
Final set: paste has hardened to the point at which it can sustain some load. Generally occurs in 5 to 8 hours.

Use Penetration of Weighted needle to determine.

Initial set occurs when needle penetrates 25mm into paste.

Final set when there is no visible penetration.

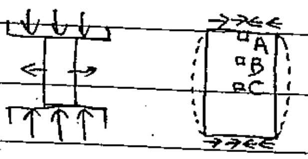
(b): The cause of capillary porosity is extra water beyond hydration needs.



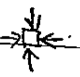
Capillary porosity depends on initial porosity (w/c ratio) and degree of hydration. For the same degree of hydration, with the increase of w/c ratio, the capillary porosity increases.

For the same w/c ratio, higher degree of hydration means lower capillary porosity.

(c) This is mainly because of the confinement effect.

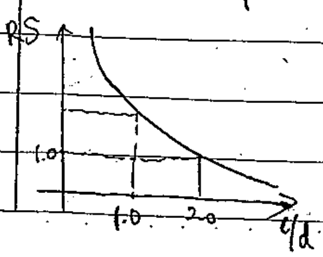


When the concrete sample is under compression, it also have a horizontal expansion as shown in the figure. Friction will be generated at the contact surface to prevent the horizontal expansion.

For point A:  Restrain is higher at the edge side ⇒ higher confinement.

For B:  Restrain is smaller because it is far from surface ⇒ lower confinement

For C:  Pure compression when $l/d \approx 2.0$ ⇒ No confinement.



Relative strength will decrease with the increase of l/d due to the confinement effect. Concrete cylinder usually have $l/d = 2$, means relative strength is almost 1. (Cont)

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But concrete cube has $l/d \approx 1$, which means its strength is 30% higher than its cylinder strength, because the confinement effect still exists at centre.

(d) Transport properties are the ease with which liquids or gases can travel through concrete.

Three types: ① Permeability: flow under a pressure differential.

② Diffusion: the process in which a fluid moves under a differential in concentration.

③ Absorption: the process in which a liquid moves due to capillary suction.

Four characteristics: ① capillary porosity ② pore size

③ continuity of pore system ④ tortuosity.

4. (a) ① Improve workability at same w/c ratio.

② Increase strength at same workability

③ Reduce cost at same w/c ratio and workability.

(b) (i) Workability of B is higher than A because they have same water to binder ratio, but fly ash is circular shape, which increases workability.

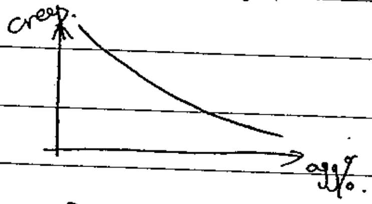
(ii) Workability of D is higher than F. They have the same w/c ratio, but F has a higher agg/c ratio, which decreases workability.

(iii) Early compressive strength C > A > B. C has lowest water to binder ratio, which decreases capillary porosity and increases strength.

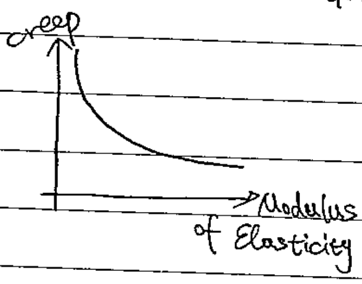
A and B have the same water to binder ratio. But B has fly ash, which creates pozzolanic reaction much later. So the early strength is lower.

(iv) E has lowest w/c ratio and also contains water reducer. Hence E has highest strength. A, D and F have the same w/c ratio, but A does not have water reducer. As a result, A has lowest strength. D, F have the same w/c ratio and water reducer, but D has more cement. Cement in concrete provides strength and stiffness. Hence, D has slightly higher strength than F ⇒ E > D > F > A.

(c) Creep is defined as the increase of strain in concrete with time under sustained stress.



Creep decreases with the increases of aggregate fraction. Aggregate is more hard and it has low creep or shrinkage compared to cement. Hence, more aggregate leads to less creep.



Creep decreases with the increases of Modulus of elasticity of aggregate. Stiffer aggregate can reduce creep.

(d) Maturity will affect the strength.

(i) $M_1 = \sum T \cdot \Delta t = 3 \times (60+10) + 25 \times (10+10) = 710$ °c-days

$M_2 = 28 \times (20+10) = 840$ °c-days

As $M_2 > M_1$, the concrete cylinder in the laboratory has higher compressive strength.

(ii) Suppose at x days they have the same maturity.

$$3 \times (60+10) + (x-3) \cdot (10+10) = x(20+10)$$

$$x = 15$$

At age of 15 days, the strength measured from the concrete cylinder can represent the strength of concrete in the precast member.