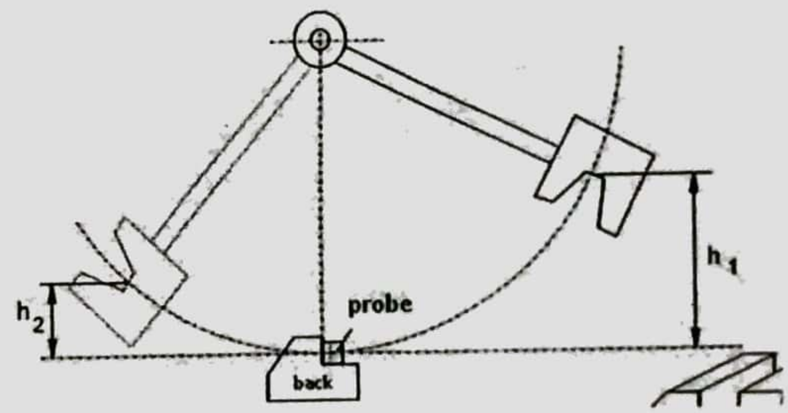
CV1013 S2 AY 2014-15 Solutions

Question 1

A. Strength → the stress required to cause permanent deformation. Strength can be measured by tensile test
Ductility → the strain the steel can endure before failing. Ductility can be measured by tensile test or bending test
Toughness → ability of steel to absorb energy prior to failure. Toughness can be measured by Charpy V-Notch Test, measuring area under stress-strain curve and fracture mechanics
Weldability → capacity of metal to be joined by welding in order to form the desired structures. Weldability can be measured by determining the carbon-equivalent content in the steel

B. Charpy V-Notch test is done by dropping some kind of "pendulum" (the V-Notch) from a certain height.



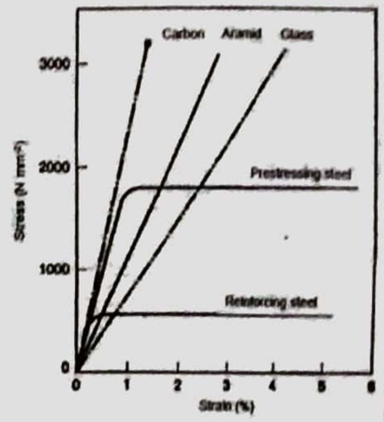
By conservation of mechanical energy, we can get

$$mgh_1 = E + mgh_2$$

Where h1 is the initial height of the V-Notch and h2 is the final height. The difference of potential energy before and after will be the energy absorbed by the steel before failing.
V-Notch is important because it helps us easily measure the energy absorbed by the steel.
Test temperature is important because it shows the toughness of the steel given a temperature. It will determine the servicibility of the steel in different climates (e.g. dry climate, tropical, desert, snow, etc.)

C. Seasoning → drying timber in a controlled manner to reduce moisture content without producing unwanted defects. They are done either with natural air or kiln drying.
Preservation → use of chemical substances which prevent fungi and insect from developing. Done by adding tar oil, water borne preservatives and organic solvent preservative

If not seasoned and preserved properly, fungi, boring insects and termites may attack wood, reducing its strength and destroying it slowly.



D. Fiber will increase the Young modulus of the steel, because the modulus of the FRP system will lie between the modulus of the steel and the fiber (fiber has higher modulus than steel), depending on the combination. This will make the system tougher and stronger.
Application of FRP in civil engineering:
- Increase flexural strength of reinforced concrete (RC) slabs
- Increase shear or flexural strength of RC beams
- Increase strength and ductility of RC columns
- Increase blast resistance of walls
- Repair and increase weathering resistance of concrete structures

E. Rain penetration → presence of pores gives way for water to enter. This can be tackled by increasing the thickness, use water resistant plaster, provide cavity lin wall and ensure good workmanship
Efflorescence → migration of soluble salts in clay to the surface, forming white crystals. This can be tackled by control water when mixing the mortar, reduce alkali sulfate in brick and prevent water from entering the masonry.
Sulphate attack → sulphate salts from brick interact with the cement. To tackle, use brick with low sulphate content

Question 2

A. Sample 1 : SD = 3 MPa n = 10 $SD^2 = 9$
Sample 2 : SD = 4 MPa n = 5 $SD^2 = 16$

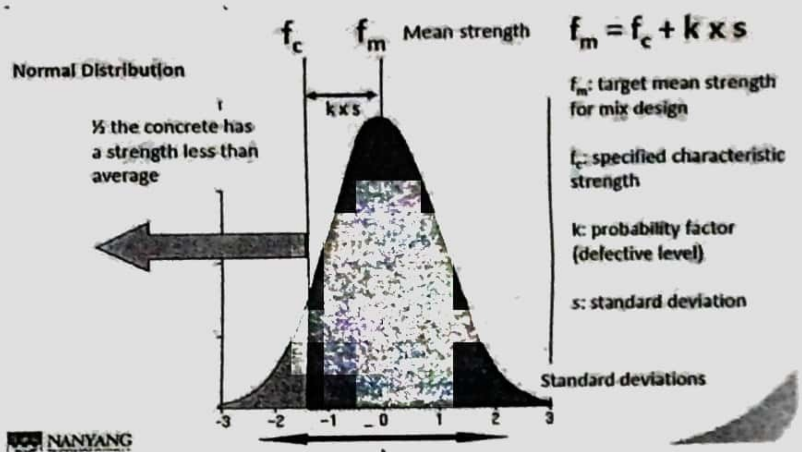
$$SD_m = \sqrt{\frac{n_1 * SD_1^2 + n_2 * SD_2^2}{n_1 + n_2}} = \sqrt{\frac{10 * 9 + 5 * 16}{15}} = 3.366$$

$$f_c = f_m + ks$$
$$fc = 10 + 2.33 * 3.366 = 17.84\ MPa$$

X 4.

PS: I am not sure the statistical formula I use for this question is accurate. I basically tried to calculate the new average variance, then square root it to get the new standard deviation. Then the fc calculation is similar to the one in the lecture. If you have any suggestion please feel free to email me at DSUGENG001@e.ntu.edu.sg. I will be more than happy for a discussion.

B. The quality of concrete mix will never be exact. In fact, it will vary and can be estimated to be normally distributed. We want the strength we get to meet the required strength. So aiming for higher mean strength will ensure that more portion will be inside the region range.



C. The hydration of slag requires the presence of CH, which is a by-product of CS_3 and CS_2 hydration. Therefore, for slag to hydrate, it must wait for CS_3 and CS_2 to hydrate first.

D. Coarse aggregates = 1000 * (1 + 0.02) = 1020 kg/m³
Fine aggregates = 1400 * (1 – 0.01) = 1386 kg/m³
Water = 200 - (1020 – 1000) + (1400 – 1386) = 194 kg/m³

If the quantities are not adjusted, we will end up with too much water, thus the w/c ratio will increase and reduce strength. In the design process, aggregates are assumed to be in SSD condition. So when aggregates are not in SSD condition, it will release or absorb water to reach SSD. Due to this, we should adjust the water added to the mix.

Question 3

A. Mass of water = 10 kg
Volume of water = volume of container = 10/1000 = $10 * 10^{-3}$ m³

Mass of aggregates = 16 kg
By density, 16 kg of aggregates should occupy 16/2600 = $6.15 * 10^{-3}$ m³
However in this problem the aggregates occupy $10 * 10^{-3}$. So there should be $3.85 * 10^{-3}$.
Void ratio = volume of air / volume of solid = 3.85/6.15 = 62.6%

B.

Factors	Workability	Compressive Strength
Increased aggregate to cement ratio	Reduced, because the cement will surround the	Not affected, because strength is determined

	aggregates, thus reducing the cement paste and free water available for workability (the paste will get somewhat "thicker"	mainly by w/c ratio instead of the aggregates to cement ratio
Addition of air entraining agent	Increased, because air entraining agent will provide air bubble which makes the concrete more workable	Reduced, because it will introduce air which increases porosity, which increases w/c ratio and reduce strength
Use of crushed aggregate ↑ SA to V ratio	Reduce, because if the angular aggregates are used, then it will require more water to cover up all the surface	Increased, because the use of angular aggregates reduce the free water, and introduce interlocking system in the concrete structure
Increased time/age	Reduce, because water will be used for hydration and reduce the water available for workability	Increase, because as hydration occur, more CSH will be produced, less water available and strength will increase
Addition of fly ash	Increase, because GGBS reduce the water requirement for the same strength water reducer	Increase, because the addition of GGBS will produce more CSH from the CH produced from cement hydration.

C. No, strength is determined by initial porosity, with which we can derive the initial w/c ratio. After setting, the initial porosity will no longer be affected because it is no longer initial condition. As ponding is done after setting, then it will not affect the initial porosity of the concrete. In fact, ponding helps strength development of the concrete.

D. Non-destructive test. It will produce slightly different results from the standard concrete testing in the lab because NDT measures some properties of the material (elasticity, sound speed, etc.) and try to find correlation with strength. So NDT would just provide some indication of strength derived from other property of material.

Question 4

A. Performance of asphalt cement is measured by the viscosity of the mix. From the graph, we can observe that type B works better than type A in higher temperature, because its viscosity is higher in temperatures above 50°C. On the other hand, type A outperforms type B in lower temperature. This can be deduced from the higher viscosity of type A in tempratures lower than 50°C.

B. Strong affinity for asphaltic binder → to prevent aggregates from flying apart when exposed to high impulse when the plane is about to take off or land.
High resistace against polishing → this is to ensure the aggregates don't lose their properties (i.e. by sinking inside the asphalt cement and losing the "roughness" from the aggregates) when exposed to huge impulse and shear force

(c) Dense-graded asphalt concrete specimens S1 and S2 respectively prepared using M1 and M2 mix designs possess the following attributes.

M_B(g)	61	62.95
V (cm³)	549	537

Specimen (mix design)	S1 (M1)	S2 (M2)
Weight, suspended in air (gram)	1,220.0	1,255.0
Weight, suspended in water (gram)	671.0	718.0
Binder content (% by weight of specimen)	5.0	5.0
Relative density of binder	1.05	1.05
Bulk relative density of aggregate	2.40	2.60
Binder absorption in the aggregate	0	0

Determine the following parameters for specimens S1 and S2:

--- bulk density, d (g/cm³);
--- voids in the total mix, VTM (%); and
--- voids filled with binder, VFB (%).

Comment on the performance of each mix design (M1 versus M2) when applied in the wearing course of asphalt concrete pavements in Singapore.

(11 Marks)

S1

M(g)		V(cm³)
0	Air	8
61	Binder	58.1
1159	Agg	482.9
1220 (total)		549 (total)

S2

M(g)		V(cm³)
0	Air	18.6
62.95	Binder	59.8
1192.25	Agg	458.6
1255 (total)		537 (total)

$VTM = \frac{8}{549} \times 100\% = 1.46\%$

$d = \frac{1220}{549} = 2.22\ g/cm^3$

$VFB = \frac{58.1}{58.1+8} \times 100\% = 87.90\%$

$VTM = \frac{18.6}{537} \times 100\% = 3.46\%$

$d = \frac{1255}{537} = 2.34\ g/cm^3$

$VFB = \frac{59.8}{59.8+18.6} \times 100\% = 76.28\%$

END OF PAPER

LTA: VTM = 3-5%, VFB = 75-82% } S2 is suitable, not S1 #.