CV1013 CIVIL ENGINEERING MATERIALS AY21/22 SOLUTION

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Q1.

(a) Toughness, surface texture, porosity and resistance to polishing are the important properties of the mineral aggregates used in the asphalt concrete wearing course of road pavements.

Toughness is the resistance to abrasion and degradation during manufacture, construction, and during service. It is important to ensure that the surfacing layer is durable and can last long periods of time without major reinstating works.

The surface texture of aggregate can be either smooth or rough. A smooth surface can improve workability. Contrarily, a rougher surface generates a stronger bond between the asphalt binder and the aggregate which results in higher strength. For the wearing course, a rougher surface is preferred as it means higher skid-resistance, ensuring smooth journeys.

Porosity is the measure of volume of voids in the mineral aggregate. A more porous aggregate would be able to contain more water or surface run-off as more voids are present. As such, for asphalt concrete wearing course of road pavements, a porous mineral aggregate would be used to prevent ponding and water build-up onto the surface of the track which is unsafe for commuters due to the possibility of hydroplaning of the tyres.

Resistance to polishing, as its name suggests, is the measure of the roughness of aggregate after a polishing load has been induced by traffic loads. To ensure longevity of the wearing course, aggregates with higher skid resistance – determined through Pendulum Skid Resistance Tester – should be used.

(b) $\rho_{agg} = 2.65g/cm^3, \rho_{binder} = 1.02g/cm^3$

$M_{BA} = 1200 \times 0\% = 0g$

$M_{BE} = 80g$

$V_{BE} = V_B = \frac{80}{1.02} = 78.431cm^3$

$V_{agg} = \frac{1200}{2.65} = 452.830cm^3$

$V_A = V - V_{agg} - V_{BE} = (1200 + 80 - 728) - 452.830 - 78.431 = 20.739cm^3$

$VTM = \frac{V_A}{V} \times 100\% = 3.757\%$

$VFB = \frac{V_{BE}}{V_{BE}+V_A} \times 100\% = 79.087\%$

Q2.

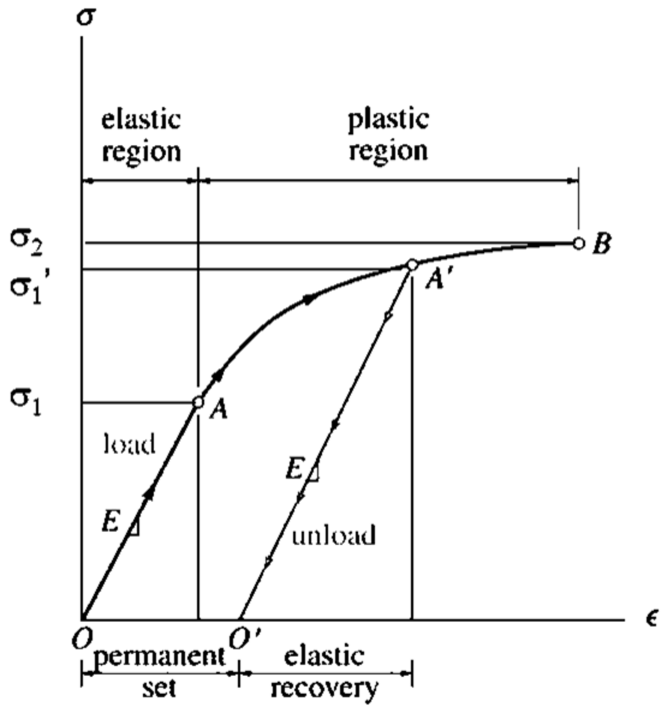
(a) A line that passes through one corner of the cube through the center and to the other corner measure $4r$, where r is the radius of an atom. Let a be the length of one unit cube of the BCC lattice structure. By geometry, length of diagonal is $a\sqrt{3}$, equating both gives:

$4r = a\sqrt{3} \rightarrow a = \frac{4r}{\sqrt{3}}$.

$$APF = \frac{N_{atoms} \cdot V_{atoms}}{V_{unit\ cell}} = \frac{2 \cdot (\frac{4}{3}\pi r^3)}{\left(\frac{4r}{\sqrt{3}}\right)^3} \rightarrow APF_{BCC} \approx 0.68$$

From the derived APF formula for BCC lattice structures, the orders of radius, r, in the numerator and denominator is the same – where both have a 3rd power. This would mean they cancel one another out and the resulting APF calculated would be the same regardless of the radius of the atoms.

(b) When a steel undergoes cold work or strain hardening, its ductility and toughness decreases, meaning that it becomes more brittle. However, it helps to establish a higher yield point for the steel, making it stronger. It should be noted that the elastic modulus remains the same.



As seen in the diagram, the increase in yield point is due to grain distortion from cold work or strain hardening. The new O' falls towards the right of O, which shows that ductility is lost as permanent deformation has occurred.

Q3.

(a)(i) Drying is necessary for wood production after sawing for a few reasons. Firstly, drawing out the moisture would prevent fungal attacks which can cause wood rot. Other than fungus, it would also eliminate any form of life (insects and their eggs) in the wood. Moreover, drying is also required before any forms of preservative treatment so that moisture held in the wood is not too high.

Drying is also necessary to bring down the moisture levels to an acceptable level, where its moisture level would not have a vast difference between that of the atmosphere. When the difference in moisture levels of wood and the atmosphere is too high, there would be uneven shrinkage which causes warps, checks, and shakes, which would be detrimental to the physical properties of the wood itself.

(ii) $diagonal\ length\ (radial\ and\ tangential\ direction) = \sqrt{2 \times (10\sqrt{2})^2} = 20cm$

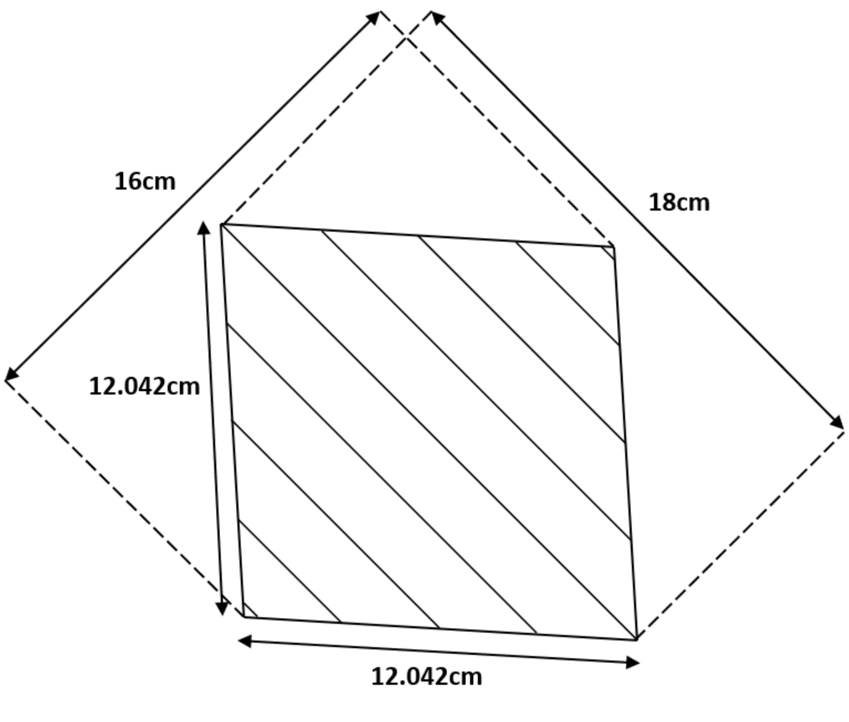
When the wooden post is dried to a moisture content of 10%, there will be a moisture content reduction of 20% from the fibre saturation point of 30%. As such,

$radial\ length = 20 \times (100 - 10)\% = 18cm$

$tangential\ length = 20 \times (100 - 20)\% = 16cm$

$length\ of\ one\ side = \sqrt{\left(\frac{18}{2}\right)^2 + \left(\frac{16}{2}\right)^2} = 12.042cm$

New cross section:



(iii) $longitudinal\ length = 1 \times (100 - 2)\% = 0.98m$

(b) For loading perpendicular to fibres:

$F_c = F_m = F_f$

$\sigma_c = \sigma_m = \sigma_f$

$\delta_c = \delta_m + \delta_f$

Where *c, m* and *f* represent composite, matrix, and fibre respectively.

From the geometry of deformation,

$\varepsilon_c = \varepsilon_m V_m + \varepsilon_f V_f$

$\frac{\sigma_c}{E_C} = \frac{\sigma_m}{E_m} V_m + \frac{\sigma_f}{E_f} V_f$

$\frac{1}{E_C} = \frac{1}{E_m} V_m + \frac{1}{E_f} V_f$ (given that $\sigma_c = \sigma_m = \sigma_f$)

$E_c = \frac{E_m E_f}{V_m E_f + V_f E_m}$ (shown)

(c) 1. Use lower water/cement ratio. When the water/cement ratio is reduced, it results in smaller spacing between the aggregates, and the aggregates would interlock effectively. This would mean the concrete mix would have high strength.

2. Use different kinds of cement paste. For high late strength, one should use cement type II, IV and V, where the C_2S content is much high and C_3S content is low. For high early strength, one should use cement type III, where the C_3S content is high and C_2S content is low.

3. Use angular and irregularly shaped aggregates. For a fixed volume or weight, angular or irregularly shaped particles have more surface are. This would mean the bonds between the aggregate and mortar would be strong, resulting in a high strength concrete.

Q4.

(a) 1. Usage of admixtures like air-entraining admixtures in the concrete mix. This is because the introduction of many dispersed air bubbles acts like a lubricant, allowing aggregates to slide past one another better.

2. Increase water/cement ratio. When the water/cement ratio is increased, it results in greater spacing between the aggregates, and the aggregates would not interlock as well. This would mean the concrete mix would have greater fluidity and workability.

3. Use rounded and smooth aggregate. For a fixed volume or weight, rounded or smooth particles have less surface area and a smaller void ratio, and they have less friction resistance too. This would mean aggregates would slide past one another easily and workability would be increased.

(b)(i) $\%\,free\ moisture\ of\ coarse\ aggregate = (0.8 - 1)\% = -0.2\%$

$\%\,free\ moisture\ of\ fine\ aggregates = (1 - 1.5)\% = -0.5\%$

Given that the percentage free moisture of both coarse and fine aggregates is negative, the aggregates would absorb water in the concrete mix to reach SSD conditions. This would mean that the water in the concrete mix would be less than that of the mix design. As such, workability would decrease, and strength would increase due to lower water/cement ratio.

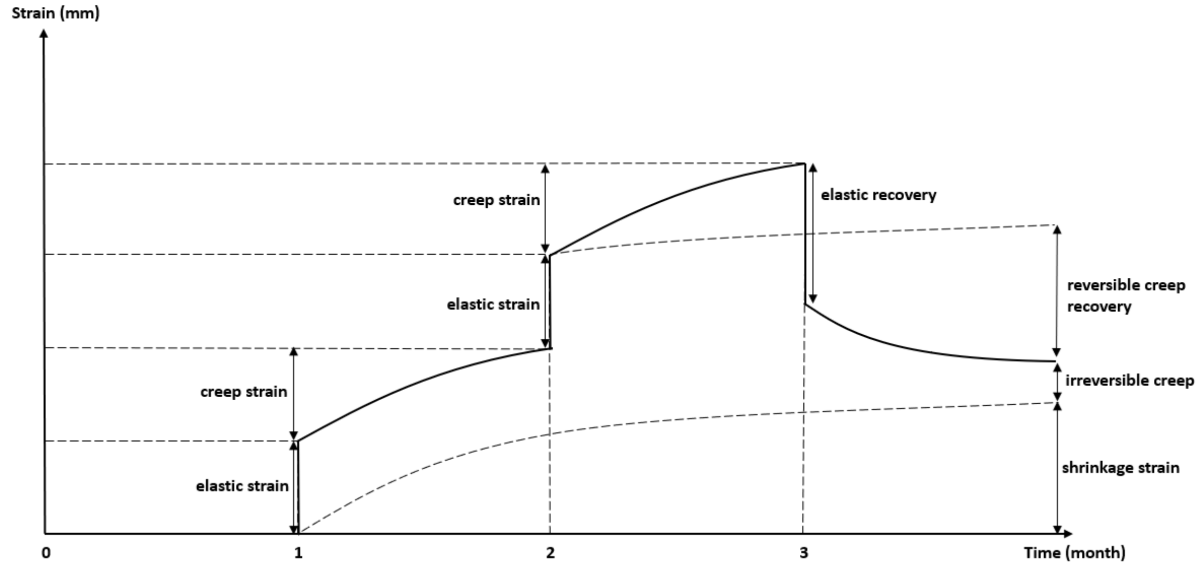
(ii) $cement_{new} = 400kg/m^3$

$water_{new} = 200 + (1000 \times 0.2\%) + (800 \times 0.5\%) = 206kg/m^3$

$coarse\ aggregate_{new} = 1000 \times 99.8\% = 998kg/m^3$

$fine\ aggregate_{new} = 800 \times 99.5\% = 796kg/m^3$

(c)



From concrete cylinder casting to one month,

Shrinkage strain does not occur during the curing process. Due to the concrete cylinder being water cured throughout, shrinkage strain would not occur as water stays in the concrete cylinder and water would not be lost to the surroundings.

From the first to second month,

A stress of 5MPa is loaded onto the cylinder. This causes elastic strain initially at the start of the first month. Throughout the month, the sustained loading causes an increase of strain in the concrete cylinder.

From the second to third month,

An additional stress of 5MPa is loaded onto the cylinder. This causes elastic strain initially at the start of the second month. Throughout the month, the sustained loading causes an increase of strain in the concrete cylinder. After the third month, all unloading of all compressive forces occurs. This results in elastic and creep recovery. There is, however, a substantial amount of irreversible creep. The final strain can be found by adding irreversible creep and shrinkage strain.

(d) 1. Ultrasonic pulse velocity test. Its fundamental principle is that velocity of sound in solid material is a function of its elastic property.

2. Rebound hammer test. Its fundamental principle is that the rebound of elastic mass depends on the surface hardness. This empirical correlation of the rebound gives a value to surface hardness and the surface hardness can then be correlated to strength.

3. Windsor probe test. Its fundamental principle is that the depth of penetration is inversely proportional to the compressive strength of concrete.

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NOTE:

Do reach out to me at KEAL0001@e.ntu.edu.sg if you have any queries regarding any of my submitted workings. Feel free to leave an email to ask any questions covered in the curriculum, will be glad to help!