CV1013 CIVIL ENGINEERING MATERIALS AY20/21 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 PAC mixture for surfacing layer of bicycle tracks (choose three properties).

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 surfacing layer, a rougher surface is preferred as it means higher skid-resistance, ensuring a safe ride for cyclists.

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 surfacing layer of bicycle tracks, a porous mineral aggregate would be used to prevent ponding and water build-up onto the surface of the track which is unsafe for cyclists due to the possibility of hydroplaning of the bicycle 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 surfacing layer, aggregates with higher skid resistance – determined through Pendulum Skid Resistance Tester – should be used.

(b) $\rho_{agg} = 2.60g/cm^3, \rho_{binder} = 1.03g/cm^3$

$M_{BA} = 1200 \times 1\% = 12g$

$M_{BE} = 75 - 12 = 63g$

$V_{BE} = \frac{63}{1.03} = 61.165cm^3$

$V_{BA} = \frac{12}{1.03} = 11.650cm^3$

$V_B = \frac{75}{1.03} = 72.816cm^3$

$V_{agg} = \frac{1200}{2.60} = 461.538cm^3$

$V_A = V - V_{agg} - V_{BE} = (1200 + 75 - 739) - 461.538 - 61.165 = 13.297cm^3$

$VTM = \frac{V_A}{V} \times 100\% = 2.481\%$

In Singapore's context, the VTM value falls out of the 3% – 5% range, as such, the mix is not suitable for use in Singapore.

Q2.

(a) The other phases are primary ferrite and primary cementite. Their fractions are 7%.

For primary ferrite and austenite:

$$\frac{0.025 - primary\ ferrite}{0.025 - 0.8} = 0.93$$

$$primary\ ferrite = 0.746\%\ carbon\ fraction\ in\ steel$$

For primary cementite and austenite:

$$\frac{6.7 - primary\ cementite}{6.7 - 0.8} = 0.93$$

$$primary\ cementite = 1.213\%\ carbon\ fraction\ in\ steel$$

(b) For ferrite:

$$ferrite\ (\%) = \frac{6.7 - 0.8}{6.7 - 0.025} = 88.4\%$$

For cementite:

$$cementite\ (\%) = \frac{0.025 - 0.8}{0.025 - 6.7} = 11.6\%$$

If pearlite is considered as one phase, its fraction in the system is 100%. This due to the carbon percentage being at 0.8% which is the eutectoid point, where pearlite transitions from one structure to another (ferrite form and cementite form).

Q3.

(a)

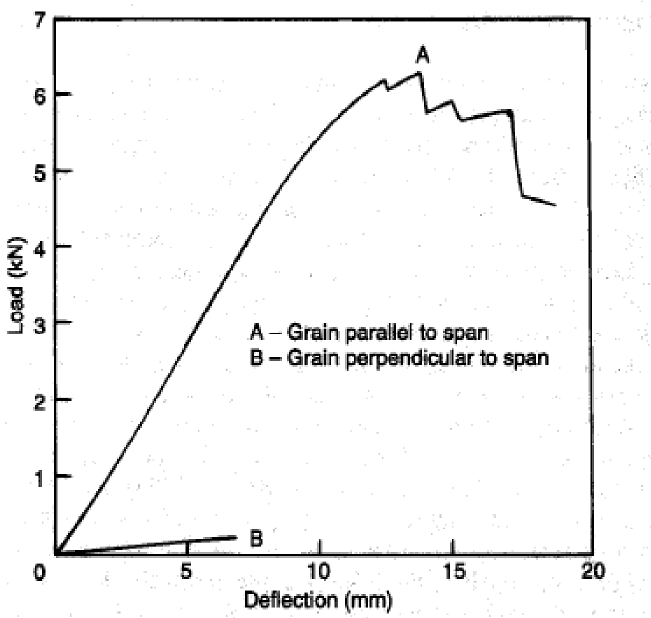


Figure 1. Jackson and Dhir (1996)

From the figure above, timber shows better performance when loaded parallel to the span as compared to when it is loaded perpendicular to the span. The deflection profiles differ vastly due to timber's anisotropic properties. The anisotropy arises from the structure of timber, where all tubular components (ray, vessel, etc) grows in the longitudinal/grain direction.

As such, it would be the strongest in the grain direction due to strong covalent bonds and any loading normal to the grain direction would be resisted well, thus more load is required for failure, as shown in the load-deflection diagram. On the other hand, the tubular components are held by weaker hydrogen bonds. Loading in the grain direction would not be resisted well and little load is required for the timber to fail.

(b) FRP2 is the better fibre-matrix combination.

In FRP1, cracking occurs in the matrix when the polymer matrix reaches its rupture strain.

In FRP2, cracking occurs in the matrix when the stress exceeds the tensile strength of the fibres.

FRP2 has a higher rupture strain than that of FRP1. This would mean that the utilization of fibre strength in FRP2 is more than FRP1, as the fibres would fail first in FRP2. This would essentially mean that the polymer matrix in FRP2 would be able to transfer and redistribute more load to the fibres through shear stresses at the fibre matrix interface as compared to the polymer matrix of FRP1, which would not transfer as much load to the fibres due to its early rupture.

As such, FRP2 would be preferred.

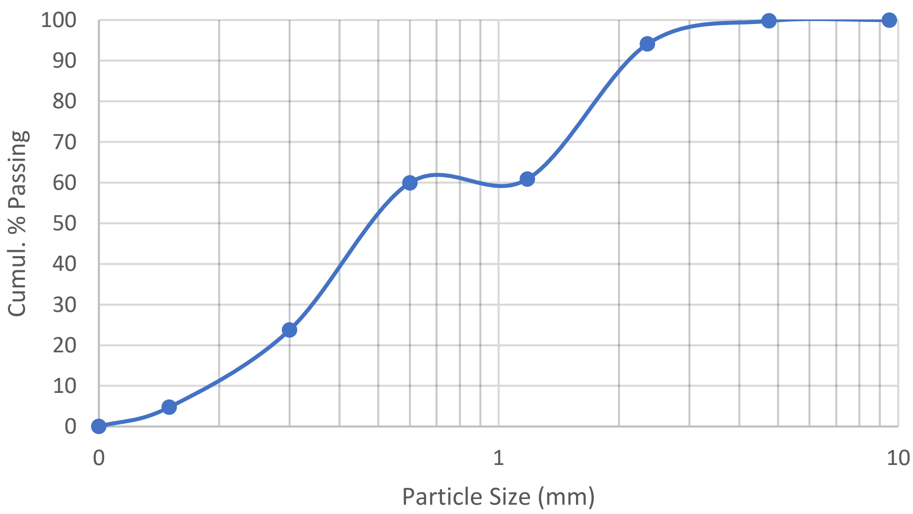
(c) $heat\ of\ hydration = \sum m \cdot s \cdot \Delta T$

$300x = (0.7x + 1.20x + 2.00x)(0.22)(4.18)\Delta T + (0.40x)(4.18)\Delta T$

$\Delta T = 57.1°C$

(d)(i)

Sieve size (mm)	9.50	4.75	2.36	1.18	0.60	0.30	0.15	Pan
Retained (g)	0.00	1.00	25.00	147.00	4.00	160.00	84.00	21.00
% Retained	0.00	0.23	5.66	33.26	0.90	36.20	19.00	4.75
Cumul. % Retained	0.00	0.23	5.88	39.14	40.05	76.24	95.25	100.00
Cumul. % Passing	100.00	99.77	94.12	60.86	59.95	23.76	4.75	0.00



(ii) 2.36mm

(iii) $fineness\ modulus = \frac{\sum cumul.\%\ retained}{100}$

$FM = \frac{0+0.23+5.89+39.15+40.05+76.25+95.25+100}{100} = \frac{256.79}{100} = 2.57$

(iv) $\%\ fines\ passing\ through\ 600\mu m\ sieve = (100 - 40.05)\% = 59.95\%$

(v) Gap-graded

Q4.

(a)

	Air-entraining admixture	Superplasticizer (same w/c ratio as the control mix)
Workability	Increased. Introduction of many dispersed air bubbles acts like a lubricant, allowing aggregates to slide past one another better.	Increased. Water entrapped within cement particles would be liberated, contributing to increased fluidity of concrete.
Early strength	Reduced. Due to the dispersed air bubbles, it would result in the formation of air voids. When this additional volume is not taken into account during concrete mix design stage, an suboptimal mix would be utilized which would not reach the target mean strength of the mix.	No change. Given that w/c ratio of the mix with superplasticizer is the same as that of the control mix, there would be no difference in the early and long-term strength of concrete.
Long-term strength		

(b) $f_m = f_c + k \cdot s$

$83.3 = f_c + (2.33)(10)$

$f_c = 60\ MPa$

(c)(i) $compacting\ factor = \frac{weight\ of\ partially\ compacted\ concrete}{weight\ of\ fully\ compacted\ concrete} = \frac{14.19-5.48}{18.88-5.48} = 0.65$

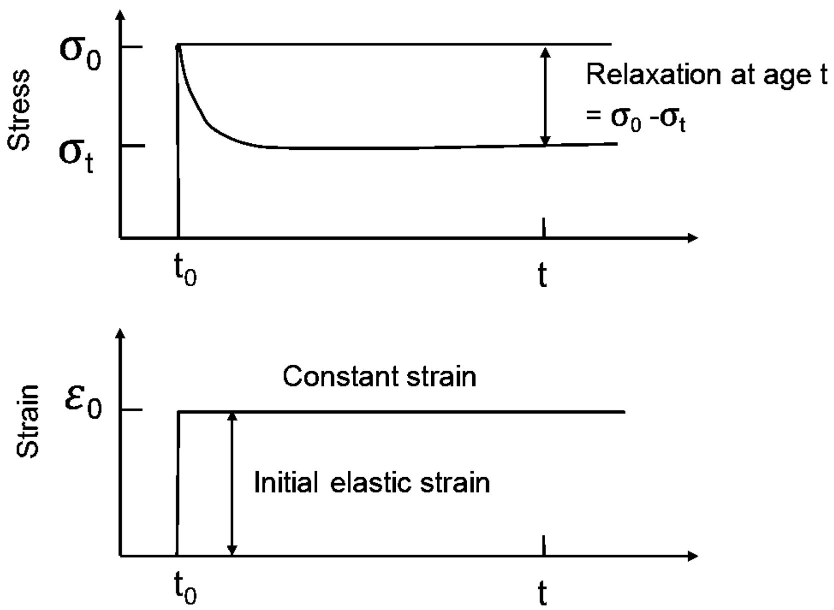
(ii) Degree of workability is very low.

(**NOTE:** Not too sure why the answer key states degree of workability = 1.54 as I can't find the exact formula, but it can be obtained by taking the inverse of compacting factor.)

(d)(i) Relaxation describes the reduction of the existing stress at a constantly applied material strain. The source which causes relaxation of hardened concrete is creep forces. Creep is the increase of strain in concrete with time under sustained stress. After long periods of time, strain in the concrete may converge to a constant value.

When this happens, the specimen can be seen to be subjected to a constant strain. Subsequently, the creep would decrease the stress progressively with time, this is known as relaxation.

(ii)



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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!