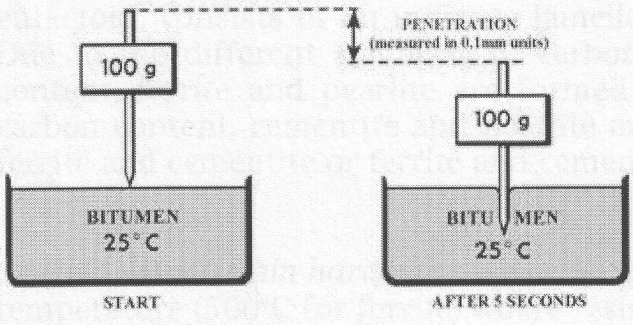
CV1013
CIVIL ENEGENEERING MATERIAL

1.(a) *Penetration test* continues to be widely used because it is easy to setup and interpret. The test consists in measuring the penetration of a needle with 100 grams of weight in a bitumen sample of 25 ^{0}C after 5 second. The apparatus and condition setup process are not so complicated. And obviously, higher values of penetration imply softer asphalts. Hence, it is often being used for testing the consistency.



However, there are some major limitations for this penetration test, includes:

- The test result is not applicable to a wide range of temperature.
- It does not cover the physical properties related to field performance (such as rutting/fatigue cracking etc.).
- It does not cover wide range of aging conditions.

(b) Three important physical properties of the mineral aggregates used in road surfacing layer for porous asphalt concrete construction are:

Size Distribution: Open graded
Angularity: Angular
Surface texture: Rough

Open gradation is important characteristic for a porous asphalt concrete since facilitates drainage. Angular aggregate and rough texture is important for providing skid-resistance.

(c)
M_G $=1250g$
M_B $=75g$
W_w $=750g$
D $=2.350g/cm^3$
$VTM=?$

M $=M_G+ M_B$
$=1250+75$
$=1325g$

D $=M/V_{MM}$
2.35 $=1325/V_{MM}$
V_{MM} $=525.532cm^3$

V $=(W_a-W_w)/ \rho_W$
$=(1325-750)/1$
$=575cm^3$

V_A $=V-V_{MM}$
$=575-525.532$
$=49.468$

VTM $=V_A/V$ x100%
$=49.486/575$ x 100%
$=$**8.6%**

It is not suitable to be used in the road in Singapore. The most desirable VTM range is 3%-5%. If VTM is too high, then there will be not sufficient strength provided to the asphalt mix. Hence, this mix is not suitable to be used.

2.(a) The hardest phase of steel is *Martensite.*
As the hardness of steel increases, strength increases while the ductility and toughness of steel decreases with the increasing amount of carbon.

(b) Pearlite, which is the microstructure formed by cooling of the austenite at the eutectoid, consists of an intimate lamellar mixture of a ferrite and cementite. Due to the different solubility of carbon, for the less weight percent carbon content, ferrite and pearlite are formed while for the higher weight percent carbon content, cementite and pearlite are formed. Hence, it can be viewed as ferrite and cementite or ferrite and cementite along with cementite and pearlite.

(c) *Cold work/strain hardening* is plastic deformation below the recrystallization temperature (500°C for ferrite) where resistance to further deformation increase with increasing amounts of deformation.

-*Advantage*: hardness and strength of the steel increases.

-*Disadvantage*: ductility and toughness of the steel decreases (steel becomes brittle). And thus, it cannot be joined by welding without softening(annealing) the material in the vicinity of the weld.

(d) *Weldability* is defined as the capacity of a metal to be joined by welding into a structure that can perform in a satisfactory manner for an intended service.

A convenient way to access weldability and to evaluate the effect of alloying elements on weldability is to use a "carbon equivalent" (CE) formula, such as

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

(e) *Directional dependence* of wood means that the variation of strength between different directions can be contributed to the anisotropic structure of the wood cells.

The tensile strength values in longitudinal: radial: tangential directions on average are in the ratio of 20: 1.5: 1.

Due to the directional dependence of the wood, woods are generally glued together for practical design. For example, plywood is glued together at right angle and Glued-laminated Timber is manufactured by gluing pieces which grain directions in all of them are parallel.

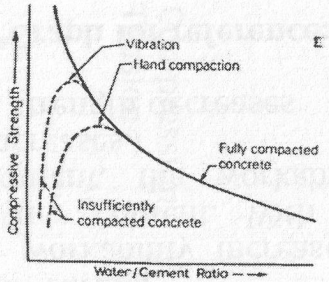
3.

No.	Cement		Aggregate		Water (kg)	Admixture (amount, kg)	Curing	Effect:			Justification
	Amount (kg)	Type	Amount (kg)	Moisture State				Workability	Early Strength	Long-term Strength	
1	10	I	40	SSD	5	None	Water	–	–	–	–
2	8	I	43	SSD	4	None	Water	Decreased	Increased	Increased	a
3	12	I	37	SSD	5	None	Water	Decreased	Increased	Increased	b
4	10	III	40	SSD	5	None	Water	Decreased	Increased	Decreased	c
5	10	I	40	AD	5	None	Water	Decreased	Increased	Increased	d
6	10	IV	40	SSD	5	Air entrainer (0.1)	Water	Increased	Decreased	Decreased	e
7	3	I	40	SSD	5	Fly ash (7)	Water	Increased	Decreased	Increased	f
8	10	I	40	Moist	5	None	Air	Increased	Decreased	Decreased	g
9	10	I	40	SSD	5	None	Heat	No change	Increased	No change	h

- For a *constant w/c ratio* (No.1 w/c ratio=5/10=0.5; No.2, w/c ratio=4/8=0.5), an *increase in the agg/c ratio* will
  -decrease workability (cement provides proper lubrications for easy mobility of aggregates. Increase in aggregate/decrease in cement will then make less paste available for aggregates)
  -increase compressive strength (more aggregates fill the spacing between the cement grains and smaller volume of residual voids not filled by hydration products.)

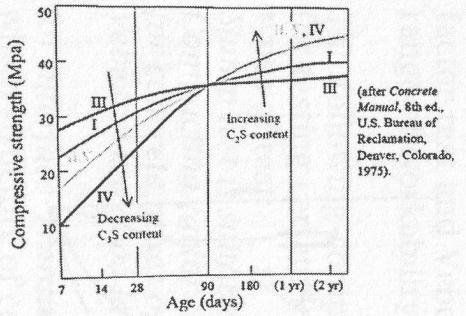
- *w/c ratio decreases* (from 0.5 to 5/12=0.42). Less water to cement ratio will
  -decrease workability (water provides workability hence decreasing w/c ratio decreases workability)
  -increase compressive strength (the lower the w/c ratio, the smaller the initial spacing between the cement grains and the smaller the volume of residual voids not filled by hydration products)

**Graph for reference:



- *Type III Cement is* used for the concrete mix design. And hence, its
  - workability decreases (Type III Cement is finer than Type I Cement. The finer the cement, the greater the water demand. Thus with the same water content, less water is used to lubricate the surface, lead to a decrease in workability.)
  - early strength is higher (Fineness controls the rate of hydration of cement, and thus affecting the strength gain.)
  - long-term strength is lower

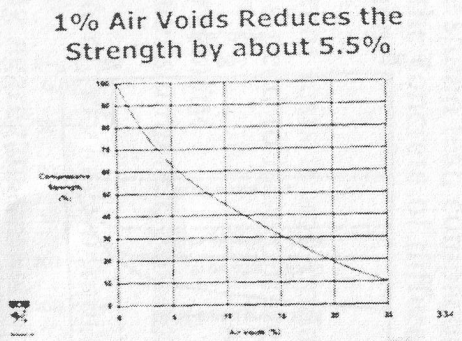
**Graph for reference:



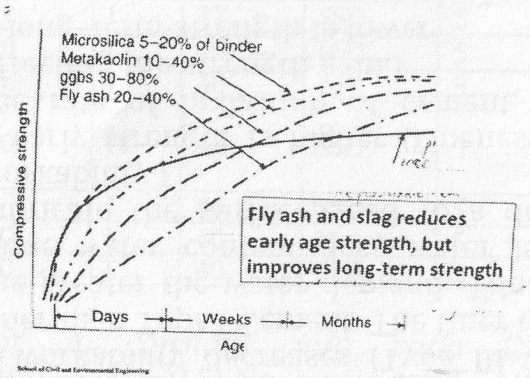
- Water is used to coat the aggregate surface which is under *air-dry* condition firstly. Hence, when aggregates are under air-dry condition,
  - workability decreases (Less water is used to lubricant the surface.)
  - compressive strength increases

- With the presence of *admixture (air entrainer)*,
  -workability increases (Air entraining agents is one of the principal admixtures affecting improvement in workability of concrete.)
  -strength decreases (1% air voids reduces the strength by about 5.5%)

**Graph for reference:

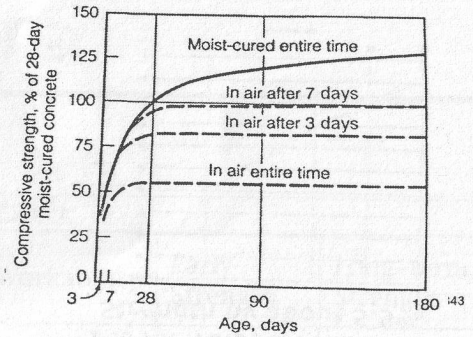


- With the substitution of *fly ash*,
  -workability increases (Fly ash is also one of the principal admixtures affecting improvement in workability of concrete by required the water content required for same degree of workability.)
  -early strength decreases
  -long-term strength increases
  **Graph for reference:

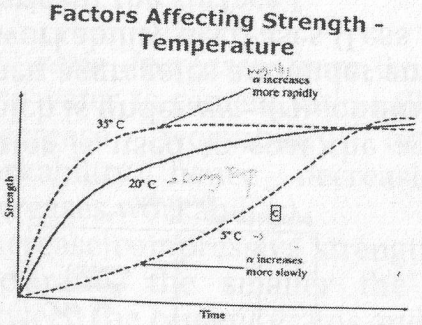


- For *aggregate under moist condition* and with *air-curing*,
  - workability increases (There is excessive water content. With the increasing water content, the workability of the concrete increases.)
  - strength decreases

  **Graph for reference:



- For a concrete with *heat curing*,
  -no change in workability (Curing is the process after final set. Since it does not involve in the mix design process, it will not affect the workability of concrete.)
  -early strength increases
  -no change in long-term strength
  **Graph for reference:



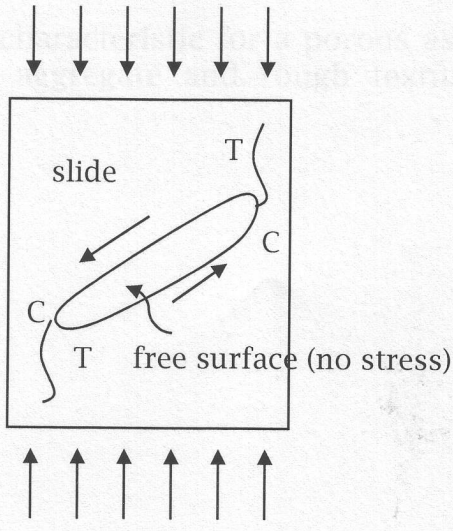
4) (a) Since different concrete has different workability and, there is a need to develop several different tests. Workability tests include slump test, compacting factor test and Vebe test, which is suitable for testing the concrete of different range of workability and under certain type of requirement.

The following comparison is stated to show that different tests is appropriate for testing certain kind of concrete. and hence there is a need to have different types of test:
Slump test is suitable for concrete of medium to high workability.
Compacting factor test is more sensitive and accurate than slump test, especially for concrete mixes of medium to low workability.
Vebe test is a good laboratory test, particularly for concrete of very low workability.

(b) *Interface Transition Zone* is a thin zone surrounding aggregate particles in which structure of cement paste is different from that of bulk paste further away from the physical interface, in terms pf density, morphology, and composition.

Interface Transition Zone is generally the weakest link of the chain and is considered the strength-limiting phase in concrete. The structure of the Interface Transition Zone, especially the volume of voids and microcracks present, have a great influence on the stiffness or the elastic modulus of concrete. The existence of the ITZ is the primary reason that concrete is more permeable than the corresponding paste.

(c) "Wing" crack occurs because concrete is weak in tension. Cracks then occur along the direction of tension. The following figure shows the formation of "Wing" crack under compressive load.



C: Compression;
T: Tension

d) Aluminum Oxide is present only as a flux to reduce the sintering temperature and contribute little to the cement strength.

(e) Water reducers may be required to lower the water required (8%–12% reduction to attain a given slump). Functions of water reducers include:
-Improve workability at same w/c ratio
-Increase strength at same workability
-Reduce cost at same w/c ratio and workability

(f) Concrete is generally high in compression and low in tension. Also, the concrete strength is determined by the weakest component, and the compressive strength in aggregates is dominant. Hence aggregate is responsible for ductility of concrete in compression but not in tension.

Low Kar Min