

Name: _____

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	Department of Civil Engineering
	Concrete Engineering and Technology
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	Assignment No 1

Problem 1, read the pairs of statements, and write A, B, C and D as defined below:

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| <ul style="list-style-type: none"> • Write A when both statements are True • Write C when statement 1 is true and 2 is false | <ul style="list-style-type: none"> • Write B when both statements are False • Write D when statement 1 is false and 2 is true |
|--|---|

1	<p>1. As the s/a is increased, the mortar content in a concrete mix decreases.</p> <p>2. Normally s/a is given as the ratio of the sand in the total aggregate content of concrete by mass.</p>
	<p>Statement 1 is false. As the s/a is increased, the sand content increases and hence the mortar content increases.</p> <p>Statement 2 is false. The ratio is usually given by volume.</p> <p>Hence the correct response is B</p>
2	<p>1. Laitance formation at the top of the concrete pour is a result of bleeding in fresh concrete.</p> <p>2. Laitance should be removed before (more) fresh concrete is poured across a construction joint.</p>
	<p>Statement 1 is false. Bleeding refers to the segregation of water from the other constituents of concrete.</p> <p>Statement 2 is true. Presence of laitance across a construction joint would introduce a plane of weakness.</p> <p>Hence the correct response is D</p>
3	<p>1. Formation of ITZ in the bottom of the coarse aggregates is a manifestation of bleeding.</p> <p>2. Segregation resistance is a desirable property in concrete.</p>
	<p>Statement 1 is true.</p> <p>Statement 2 is true</p> <p>Hence the correct response is A</p>
4	<p>1. In principle, as the compaction factor increases, the slump decreases.</p> <p>2. Slump and slump flow of concrete are both measured in mm or cm.</p>
	<p>Statement 1 is false.</p> <p>Statement 2 is true.</p> <p>Hence the correct response is D</p>
5	<p>1. A slump cone measures 100mm (top diameter), 200mm (bottom diameter) and 350mm (height).</p> <p>2. The slump test helps in qualitatively understanding the setting time of concrete.</p>
	<p>Statement 1 is false. The height of the slump cone is 300mm</p> <p>Statement 2 is false. It is measure of workability.</p> <p>Hence the correct response is B</p>
6	<p>1. Hydration of cement begins as soon as water comes in contact with the cement.</p> <p>2. Hydration of OPC is an exothermic reaction.</p>
	<p>Statement 1 is true</p> <p>Statement 2 is true</p> <p>Hence the correct response is A</p>
7	<p>1. Quality control of concrete construction is usually based on strength tests carried out at an age of 28 days.</p> <p>2. Strength development in concrete is completed in about a month.</p>
	<p>Statement 1 is true</p> <p>Statement 2 is false. It is only a matter of engineering judgement that 28-day strength is taken for the purpose of quality control.</p> <p>Hence the correct response is C</p>

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	<i>Additional comment: Pl also see another question in the assignment relating to strength development in concrete containing mineral admixtures.</i>
8	<ol style="list-style-type: none"> 1. Characteristic strength of concrete is normally defined as the strength that is likely to be exceeded 95% of the times. 2. If instead of allowing 5% of samples to fall below the characteristic strength, 10% of the samples are allowed to fall below the characteristic strength, the design strength (of the mix) will be higher.
	<p><i>Statement 1 is true.</i></p> <p><i>Statement 2 is false. In fact, if 50% of the samples were allowed to fall below the characteristic strength value, the two (characteristic and the target strength) will be the same !!)</i></p> <p><i>Hence the correct response is C</i></p>
9	<p>The target strength (T) for which a concrete mix is proportioned is often determined as $(f_{ck} + k\sigma)$. Now, here</p> <ol style="list-style-type: none"> 1. k and σ both depend on the percentage of samples allowed to fall below f_{ck} 2. a low value of σ represents a low level of quality control at site.
	<p><i>Statement 1 is false. Whereas the 'k' indeed depends on the said percentage, the σ is not. The latter is a measure of the quality control, with a higher σ meaning a greater spread in the values and therefore poorer quality control.</i></p> <p><i>Statement 2 is false. See the comment above.</i></p> <p><i>Hence the correct response is B</i></p>
10	<ol style="list-style-type: none"> 1. Concretes cured at higher temperatures initially leads to lower early strengths. 2. Curing is a process that facilitates (eases) hydration.
	<p><i>Statement 1 is false. When a concrete is cured at elevated temperatures in its early age, it gains strength rapidly, though there is evidence to suggest that the ultimate or long term strength is lower than concrete cured at normal temperatures.</i></p> <p><i>Statement 2 is true.</i></p> <p><i>Hence the correct response is D</i></p>

Problem 2 Identify the correct response(s) in the following questions. Please note that there may be more than one 'right' response.			
1	Which of the following is/are hydration product of OPC.		
	(a)	<i>Alite</i>	(b) <i>Ettringite</i>
	(c)	<i>Monosulphate</i>	(d) <i>Calcium hydroxide</i>
<i>Apart from alite, all are hydration products. Hence the correct response is B, C and D.</i>			
2	Which of the following is/are a constituent of OPC		
	(a)	C_3A	(b) <i>Portlandite</i>
	(c)	Na_2O	(d) <i>Gypsum</i>
<i>Portlandite (calcium hydroxide) is a hydration product. All the others are a part of the OPC. Whereas C_3A is one of the complexes, Na_2O is an alkali oxide present as an impurity. Gypsum is added to the clinker at the time of grinding the clinker to produce OPC and is hence an integral part of the OPC. Indeed, gypsum is NOT a part of the clinker !! Hence the correct response is A, C and D.</i>			
3	False set occurs in a cement when		
	(a)	<i>High gypsum and high aluminate content</i>	(b) <i>Low gypsum and high aluminate content.</i>
	(c)	<i>Low gypsum and low aluminate content</i>	(d) <i>High gypsum and low aluminate content.</i>
<i>Hence the correct response is D.</i>			
4	If in an application, higher ultimate strength is desired, which of the cements is the most suitable.		
	(a)	<i>One that has a high C_3S content</i>	(b) <i>One that has a high C_2S content</i>
	(c)	<i>One that has a high C_3A content</i>	(d) <i>One that has very little gypsum.</i>
<i>C_3A contributes to strength in the initial part of the hydration, whereas both C_3S and C_2S contribute to strength in the later period. Among the latter two, C_2S continues to hydrate over a longer period and is a preferred constituent in high strength concrete. Hence the correct response is B.</i>			
5	Considering the effect of the properties of coarse aggregate used in concrete, which of the following statements is/are true.		
	(a)	<i>Strength of aggregates is not a governing criteria in lower strength concrete</i>	(b) <i>The quantity of water required for a given workability is higher if the maximum size of the aggregates is smaller.</i>
	(c)	<i>The quantity of water required for a given workability is higher if the aggregates are angular (compared to rounded)</i>	(d) <i>Coarse aggregates used in concrete should be in saturated surface dry condition</i>
<i>All the above statements are true. In normal strength concrete, the strength of the coarse aggregate is 'assumed' to be much higher than the surrounding mortar, and hence the statement (a) is true. As the maximum size of the aggregate is increased, the surface area increases, and so does amount of mortar required and therefore the water demand goes up too. Hence the statement (b) is true. Angular aggregates have a greater tendency for interlocking and hence for a given level of workability of mortar, the maximum volume that can be supported is lower compared to rounded aggregates. Hence the statement (c) is true. Coarse aggregates (or even fine aggregates for that matter) are expected to neither absorb the mixing water or add to it. The two cases are likely to arise if the aggregate is 'dry' or it is 'wet' respectively. In other words the water determined or required to be used from workability considerations is based on the premise that the aggregates (both fine and coarse) are in a saturated surface dry state – i.e. they will neither absorb nor release water into the mix!! Thus, statement (d) is true. Hence the correct response is A, B, C and D.</i>			

Problem 3 Answer the following questions

- 1) For a concrete with the following constitution [W = 180, C = 360, Fine stone dust = 85, Sand = 542, coarse stone dust = 172, and Coarse aggregate = 1093], what may be taken as the volumetric paste and mortar content. Ignore air content, take specific gravity of all stone dust to be 2.65 and that of cement, sand and coarse aggregate to be 3.12, 2.64 and 2.74, respectively, and assume that all the quantities given are in kgs/m^3 .
- 2) The specific gravity and bulk density of a coarse aggregate is found to be 2.7 and 1500 kgs/m^3 . Estimate the void content in the sample used to determine the bulk density.
- 3) Write a short note defining 'porosity' of a material and how it is different from 'permeability'.
- 4) Give reasons for the following
 - (A) Design and quality control measures sometimes allow upto 91 days to determine if the concrete reaches strength (instead of the more common 28days) in cases when blended cements or mineral admixtures are used in concrete construction.
 - (B) Strength of concrete reduces as the water-cement ratio is increased, in the normal range of operations
 - (C) Specifications give a minimum value for the IST and a maximum value for the FST

1. (a) water, cement and the fine stone dust will contribute to the paste phase [$180 + 360/3.12 + 85/2.65 = 327.46$ litres]
- (b) in addition to cement paste, the sand and the coarse stone dust will contribute to the volumetric mortar phase [$327.46 + 542/2.64 + 172/2.65 = 597.67$ litres]

Additional notes:

- i) Indeed the mortar content can also be calculated by subtracting the coarse aggregate volume [$1093/2.74$] from 1000, and the answer would be the almost the same !! (601.1liters) [Why is there a slight error in the numbers !!]
- ii) Please verify that when the unit quantity (in kgs/m^3) of any of the constituents is divided by the specific gravity, the answer is the volume of that constituent in liters.
- iii) The answer can also be expressed in percentage terms – the paste and mortar being 33% and 60% *by volume) and the coarse aggregate making up 40% of the concrete.

2.

The sp gr of 2.7 means that the weight of solid 1000 liters of the coarse aggregate = 2700 kg
 Given that the weight of measured sample = 1500 kg
 It is clear that a volume of aggregate missing = $1200/2.74 = 438$ liters
 Percentage of voids = 43.8%

Alternatively, it can be found that the solid volume from the bulk density is only $1500/2.74 = 562$ liters, which also gives the void content to be $1000 - 562 = 438$ liters

3.

Porosity basically is a measure of the amount of pores in a material and can therefore be expressed a volume percentage (wrt total volume, or solid volume, etc.). In absolute terms, it can be measured in terms of cc/cc etc. on the other hand permeability is the ability of a 'fluid' to pass through a medium (or a material). It is easy to understand that, in simple terms, the amount of material that flows through a barrier would depend upon factors such

as the extent of the pores, the area through which the flow occurs and thickness of the barrier, apart from the difference in concentration or pressure on the two sides of the barrier, besides the properties of the fluid involved. For example, it will be more difficult for a more viscous fluid to flow than a low viscous one, and so on. The latter idea is captured in 'permeability'.

Additional remark: An interested reader may refer to the definition and discussion of Darcy's law or Fick's law in a standard textbook.

4) Reasons

A) Design and quality control measures sometimes allow upto 91 daysblended cements or mineral

admixtures are used in concrete construction: it is because the presence of mineral admixtures (separately or as a part of the cement, as in the case of using blended cements) implies that strength development will continue for a longer period. This is because there is evidence to suggest that the secondary hydration reaction involving the silica from the mineral admixture and the calcium hydroxide from the primary hydration reaction (reaction of water with the constituents of cement) is a slower reaction. Thus, a greater time is 'allowed' for strength development in such cases. It should also be borne in mind that in several cases where concrete is used, the structure is subjected to full load (service load) only much later than 28 (or even 91 day for that matter), and hence there is reason to 'allow' more time for strength development.

B) Strength of concrete reduces as the water-cement ratio is increased, in the normal range of operations : the water-cement ratio may be taken to be between 35-40% and 50-55% in the normal range of operations. Now in this range, the water added is clearly higher than that that can be 'fully' consumed in the hydration of cement. It may be noted that the amount of water for complete hydration may be seen to be in the range of 18-22% in the literature, depending upon the characteristics of the cement involved. Now, the water added to the concrete over and above the requirement from the point of view of hydration remains in the concrete and evaporates over a period of time leaving behind pores of different sizes. This phenomenon is at the root of the porosity in concrete, and it is clear that as the water-cement ratio increases, this excess water is more, given that the amount of water required for and consumed during hydration is more or less constant. Independently, it is intuitively clear that the strength of a material would be inversely proportion to the porosity, i.e. higher the porosity lower the strength. Thus, higher the water-cement ratio, lower the strength of concrete in the normal range of operations.

Additional comment : in the normal range, the coarse aggregate is 'assumed' to be much stronger, and hence the strength of the concrete is essentially governed by the mortar phase (and the strength of the intermediate transition zone between the mortar and the aggregate)

C) Specifications give a minimum value for the IST and a maximum value for the FST : when using cement based products such as concrete, there are two fundamental considerations – (a) some time should be available to the engineer to be able to mix, transport, place and consolidate the concrete, without it becoming 'too stiff to be molded' and, (b) after the concrete has been placed in position, it should quickly begin to stiffen and gain strength. This is spirit and the requirement that is captured in the specification a +minimum IST and a maximum FST. Whereas the former ensures condition (a), the latter arises from condition (b) mentioned above.

Additional comment : It is important to understand that the setting process in concrete is different from that in cement paste – in the latter case, it is more a matter of the quality control of the material (cement) and the test is carried out under very controlled conditions, whereas in the case of concrete the situation is more an engineering exercise and the several factors, such as the proportion of concrete mixes, time required for transportation, the ambient placing temperature, etc. all come into play when deciding a required minimum on the IST and maximum on the FST. Though both are based on penetration resistance, the methods used to determine the setting times of paste and concrete are different and exhaustively discussed in the lectures.