First Semester Examination
2020/2021 Academic Session

February 2021

EAS153 – Civil Engineering Materials

Duration : 2 hours

Please check that this examination paper consists of **TWELVE (12)** pages of printed material including appendix before you begin the examination.

Instructions : This paper contains **SIX (6)** questions. Answer **FOUR (4)** questions.

All questions **MUST BE** answered on a new page.

1. You work as a technical manager for a renowned ready mixed concrete producer. Your main responsibility is to ensure the quality of the concrete produced, in relation to compliance with all the stipulated requirements. Your recent task is to supply concrete for the expansion project of the Penang Sea Port to cater for the increasing demand with regards to cargo handling and storage at the port. Due to the aggressive nature of the marine exposure condition, ordinary Portland cement concrete with characteristic strength of 50 MPa has been prescribed with maximum allowable water/cement ratio of 0.45 and minimum celment content of 400 kg/m^3 to ensure adequate durability in marine exposure and high slump of 175 mm to facilitate placement in heavily reinforced structural members. The aggregates should consist of good quality river sand with percentage passing 600 µm sieve of 60% and granite coarse aggregate with 20 mm maximum size, with the combined aggregates' specific gravity value of 2.70 in saturated and surface dry condition.

   (a). Using your vast knowledge and experience on concrete mix design, determine the quantity of materials for a trial mix of 0.08 m^3. Considering your vast experience, you may want to use a small margin of 5 MPa. Use the extract from "Design of Normal Concrete Mixes" (BRE Report, 1988). **Include all the figures and tables used with your answer.**

   [15 marks]

   (b). If the sand and granite used in (a) are having moisture content of 1.5 % and 1.0 %, respectively, determine the mix proportions for 1 m^3 and for the trial mix of 0.08 m^3.

   [5 marks]

(c). If the concrete registers lower workability than the stipulated slump value after considering the moisture condition of the aggregates, explain appropriate measure that could be taken to achieve the required level of workability, but without altering the mixture compositions of the concrete.

[5 marks]

2. The construction of a highway bridge requires that the concrete to be used for the foundation has low heat evolution characteristic and at the same time possesses adequate resistant to sulphate from the soil and ground water.

(a). Discuss the important characteristics that a Portland cement should have in order to ensure low heat evolution and better sulphate resistance.

[9 marks]

(b). Explain the suitability of the Portland cement with oxide compositions given in **Table I** for the construction of the foundation of the highway bridge.

[9 marks]

Table 1: Oxide compositions of a Portland cement

Oxide Compositions (%)	
CaO	63
SiO_2	20
Al_2O_3	6
Fe_2O_3	3
MgO	1.5
SO_3	2
K_2O, Na_2O}	1
Insoluble residue	1
Loss on ignition	2
Others	0.5

(c). Identify suitable EN 197-1 cement that could be used to reduce heat evolution and at the same time increase sulphate resistance of concrete. Discuss how the use of the selected cement contributes towards the prescribed characteristics (i.e. lower heat evolution and superior sulphate resistance).

[7 marks]

3. (a). **Table 2** provides the grading of two samples of sand A and B in term of weight retained on the relevant sieves. Determine the fineness modulus for each sand sample. Based on the fineness modulus value, explain which sand will require greater water content to achieve comparable workability when used in concrete, assuming the quantity and characteristics of other materials used are the same.

[12 marks]

Table 2: Grading of Sand

Sieve Size	Weight Retained (g)	
	Sand A	Sand B
10 mm	0	0
5 mm	0	0
2.36 mm	2.7	68.1
1.18 mm	6.9	138.0
600 µm	11.1	114.1
300 µm	259.2	84.9
150 µm	173.1	48.8
Pan	2.0	1.1

...5/-

(b). The construction of a single storey reinforced concrete school building has been proposed in a remote area of Sarawak, where access to domestic water supply is not available. Nonetheless, there is a natural pond not far from the proposed location where the water could be used as concrete mixing water. Limited tests have been performed to ascertain the suitability of the pond water as concrete mixing water, with the results shown in **Table 3**. Comment on the suitability of the pond water as concrete mixing water based on the limited test results.

[5 marks]

Table 3: Test for Suitability of Water as Concrete Mixing Water

Source of Water	Initial Setting Time of Cement Paste (min)	28-day Compressive Strength of Mortar (MPa)
Distilled Water	75	30
Pond Water	82	28

(c). The proportions of two concrete mixes are given in **Table 4**. Discuss the probable difference with regards to the workability and the 1-day strength of the two concrete mixes.

[8 marks]

Table 4: Mixture Proportions of Concrete

Concrete Mix	Ordinary Portland Cement (kg/m^3)	Fly Ash (kg/m^3)	Sand (kg/m^3)	Granite (kg/m^3)	Water (kg/m^3)
A	340	-	725	1130	205
B	238	102	725	1130	205

4. (a). Explain the term “curing” and discuss how curing could influence the durability performance of concrete.

[12 marks]

(b). Consider the high strength concrete mixtures in **Table 5**. Compare and discuss the potential difference with regards to compressive strength development between the two concrete mixtures.

[13 marks]

Table 5: Mixture proportions of high strength concrete

Concrete Mix	Portland Cement (kg/m^3)	Silica Fume (kg/m^3)	Sand (kg/m^3)	Granite (kg/m^3)	Water (kg/m^3)	SP (kg/m^3)
A	450	-	675	1125	126	12
B	382.5	67.5	675	1125	126	12

5. Defect, disease and decay (3D) affects the quality of timber. It reduces the strength, spoil the appearance and lower the value of timber.

(a). Explain with example the differences between defect, disease and decay (3D).

[12 marks]

(b). Explain how this 3D affects the structural performance of timber.

[6 marks]

(c). As an engineer, name **ONE (1)** timber species that is suitable to be used as structural column and give **THREE (3)** reasons to support your answer.

[7 marks]

6. Fired clay brick and concrete masonry unit (CMU) are commonly used as building material in construction. To produce a good fired clay brick unit, it must be sintered at a high temperature to become hard and strong. For concrete masonry unit, the process is different where there is no firing process and yet the unit is strong and durable. Both of these materials are good in term of structural performance.

(a). Give **ONE (1)** difference between fired clay brick and concrete masonry unit.

[1 marks]

(b). By using simple flow charts, explain the manufacturing process for fired clay brick and concrete masonry unit.

[14 marks]

(c). **Table 6** shows the results of compression testing for fired clay brick and concrete masonry unit. Calculate the compressive strength for both materials.

[2 marks]

Table 6

	Fired clay brick	Concrete masonry unit
Size (mm) (height, width, Length)	65 x 102 x 205	190 x 190 x 400
Force (kN)	60	188

(d). "CMU is more environmentally friendly than fired clay brick". Discuss the statement.

[8 marks]

APPENDIX
INDEX NO:____________

Concrete mix design form

Job title ....

Stage	Item	Reference or calculation	Values
1	1.1 Characteristic strength	Specified	________ N/mm^2 at ________ days Proportion defective ________ %
	1.2 Standard deviation	Fig 3	________ N/mm^2 or no data ____ N/mm^2
	1.3 Margin	C1 or Specified	(k = ______) ______ × ______ = ______ N/mm^2 ______ N/mm^2
	1.4 Target mean strength	C2	______ + ______ = ______ N/mm^2
	1.5 Cement type	Specified	OPC/SRPC/RHPC
	1.6 Aggregate type: coarse Aggregate type: fine		Crushed/uncrushed Crushed/uncrushed
	1.7 Free-water/cement ratio	Table 2, Fig 4	________ } Use the lower value [ ]
	1.8 *Maximum free-water/cement ratio*	*Specified*	________
2	2.1 Slump or Vebe time	Specified	Slump ________ mm or Vebe time ______ s
	2.2 Maximum aggregate size	Specified	______ mm
	2.3 Free-water content	Table 3	________ [ ] kg/m^3
3	3.1 Cement content	C3	______ ÷ ______ = ______ kg/m^3
	3.2 *Maximum cement content*	*Specified*	______ kg/m^3
	3.3 *Minimum cement content*	*Specified*	______ kg/m^3
			use 3.1 if ⩽ 3.2 use 3.3 if > 3.1 [ ] kg/m^3
	3.4 Modified free-water/cement ratio		________ [ ]
4	4.1 Relative density of aggregate (SSD)		________ known/assumed
	4.2 Concrete density	Fig 5	______ kg/m^3
	4.3 Total aggregate content	C4	______ − ______ − ______ = ______ kg/m^3
5	5.1 Grading of fine aggregate	Percentage passing 600 μm sieve	________ %
	5.2 Proportion of fine aggregate	Fig 6	________ %
	5.3 Fine aggregate content	C5	______ × ______ = [ ] kg/m^3
	5.4 Coarse aggregate content	C5	______ − ______ = [ ] kg/m^3

Quantities	Cement (kg)	Water (kg or *L*)	Fine aggregate (kg)	Coarse aggregate (kg) 10 mm	20 mm	40 mm
per m^3 (to nearest 5 kg)	____	____	____	____	____	____
per trial mix of ______ m^3	____	____	____	____	____	____

Items in italics are optional limiting values that may be specified (see Section 7)

1 N/mm^2 = 1 MN/m^2 = 1 MPa (see footnote to Section 3).
OPC = ordinary Portland cement; SRPC = sulphate-resisting Portland cement; RHPC = rapid-hardening Portland cement.
Relative density ≡ specific gravity (see footnote to Para 5.4). SSD = based on a saturated surface-dry basis.

Table 2 Approximate compressive strengths (N/mm^2) of concrete mixes made with a free-water/cement ratio of 0.5

Type of cement	Type of coarse aggregate	Compressive strengths (N/mm^2) Age (days) 3	7	28	91
Ordinary Portland (OPC) or sulphate-resisting Portland (SRPC)	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
Rapid-hardening Portland (RHPC)	Uncrushed	29	37	48	54
	Crushed	34	43	55	61

1 N/mm^2 = 1 MN/m^2 = 1 MPa (see footnote on earlier page).

Table 3 Approximate free-water contents (kg/m^3) required to give various levels of workability

Slump (mm)		0-10	10-30	30-60	60-180
Vebe time(s)		>12	6-12	3-6	0-3
Maximum size aggregate (mm)	Type of aggregate				
10	Uncrushed	150	180	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205

Note: When coarse and fine aggregates of different types are used, the free-water content is estimated by the expression

$$\tfrac{2}{3} W_f + \tfrac{1}{3} W_c$$

where W_f = free-water content appropriate to type of fine aggregate
and W_c = free-water content appropriate to type of coarse aggregate.

5.3 Determination of cement content (Stage 3)

The cement content is determined from calculation C3:

$$\text{Cement content} = \frac{\text{free-water content}}{\text{free-water/cement ratio}} \qquad \ldots C3$$

The resulting value should be checked against any maximum or minimum value that may be specified. If the calculated cement content from C3 is below a specified minimum, this minimum value must be adopted and a modified free-water/cement ratio calculated which will be less than that determined in Stage 1. This will result in a concrete that has a mean strength somewhat higher than the target mean strength. Alternatively, the free-water/cement ratio from Stage 1 is used resulting in a higher free-water content and increased workability.

On the other hand, if the design method indicates a cement content that is higher than a specified maximum then it is probable that the specification cannot be met simultaneously on strength and workability requirements with the selected materials. Consideration should then be given to changing the type of cement, the type and maximum size of aggregate or the level of workability of the concrete, or to the use of a water reducing admixture.

5.4 Determination of total aggregate content (Stage 4)

Stage 4 requires an estimate of the density of the fully compacted concrete which is obtained from Figure 5 depending upon the free-water content and the relative density* of the combined aggregate in the saturated surface-dry condition (SSD). If no information is available regarding the relative density of the aggregate an approximation can be made by assuming a value of 2.6 for uncrushed aggregate and 2.7 for crushed aggregate. From this estimated density of the concrete the total aggregate content is determined from calculation C4:

$$\text{Total aggregate content} = D - C - W \qquad \ldots C4$$
(saturated and surface-dry)

where D = the wet density of concrete (kg/m^3)
C = the cement content (kg/m^3)
W = the free-water content (kg/m^3).

*The internationally known term 'relative density' used in this publication is synonymous with 'specific gravity' and is the ratio of the mass of a given volume of substance to the mass of an equal volume of water.

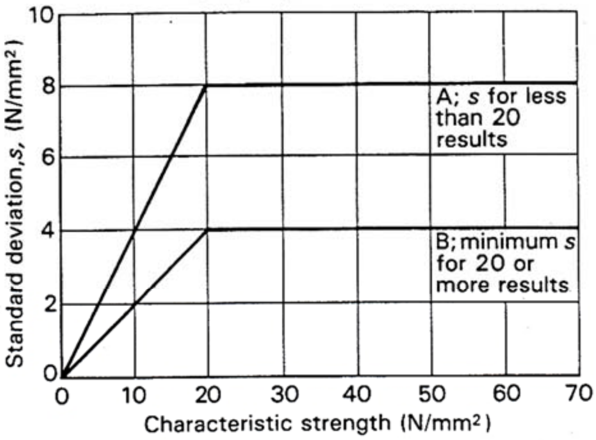

Figure 3 Relationship between standard deviation and characteristic strength

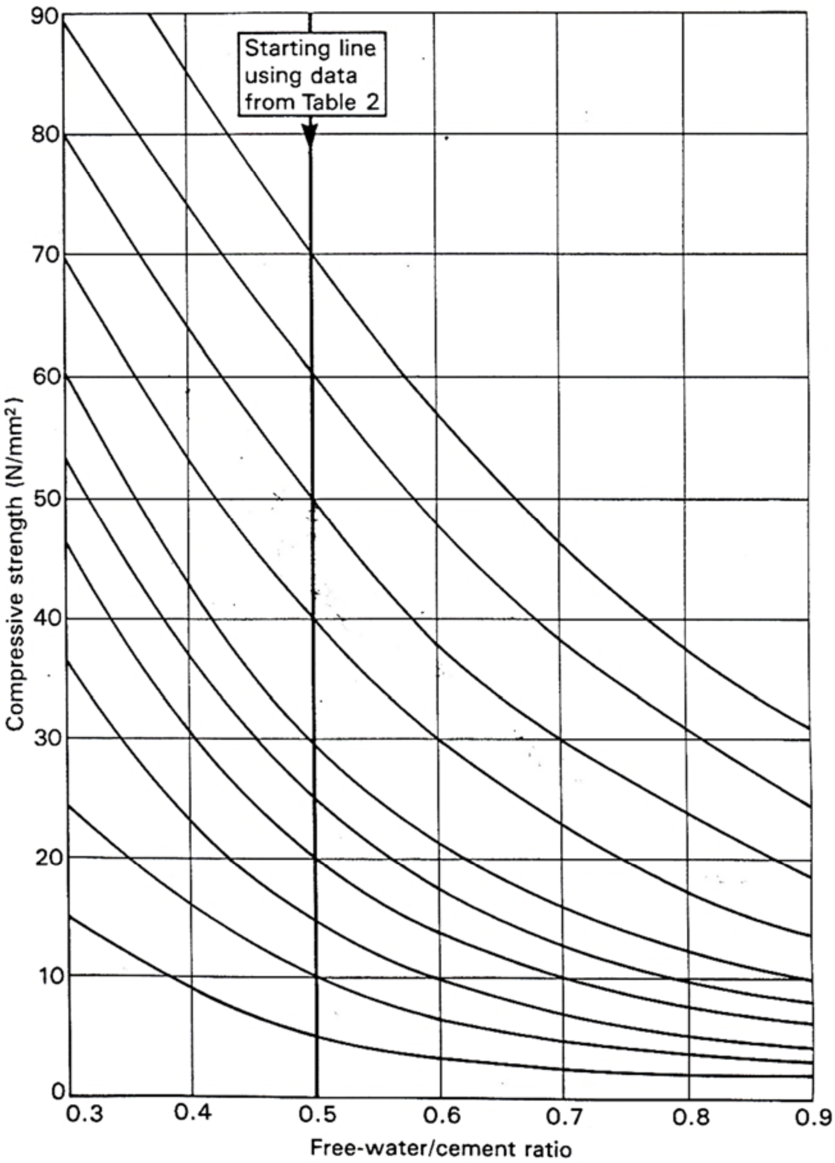

Figure 4 Relationship between compressive strength and free-water/cement ratio

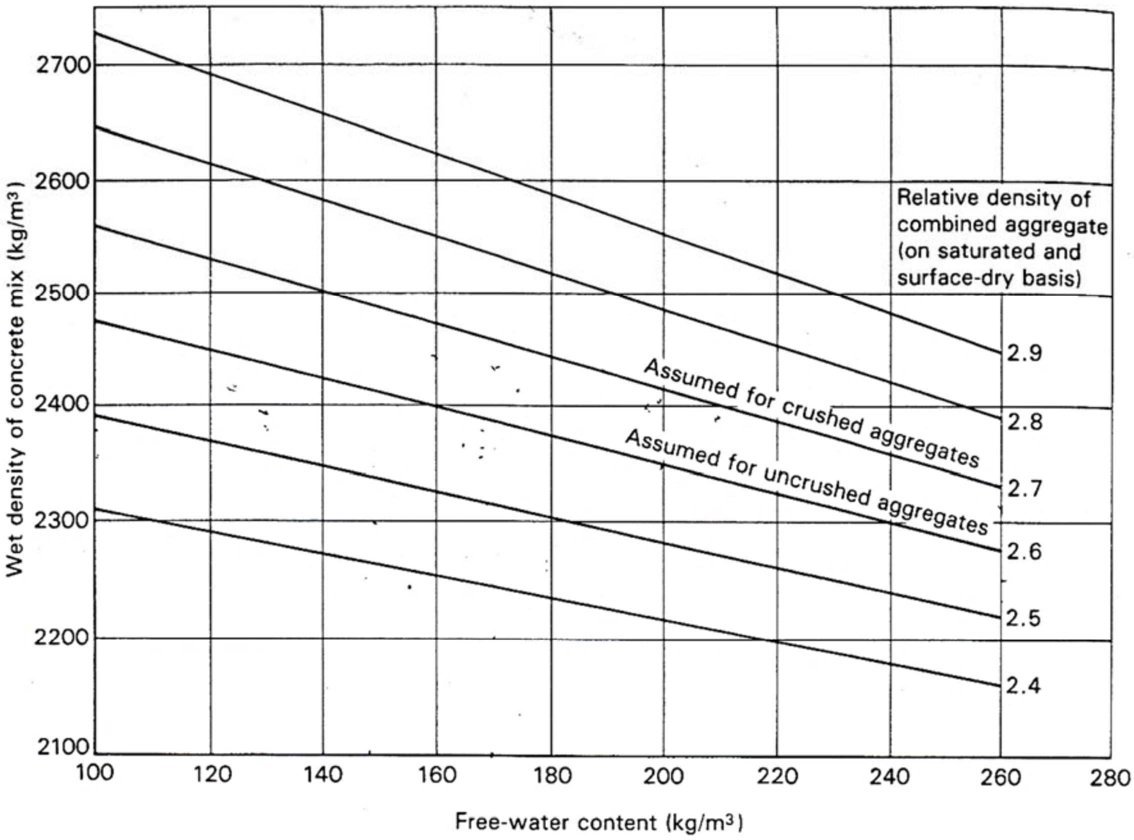

Figure 5 Estimated wet density of fully compacted concrete

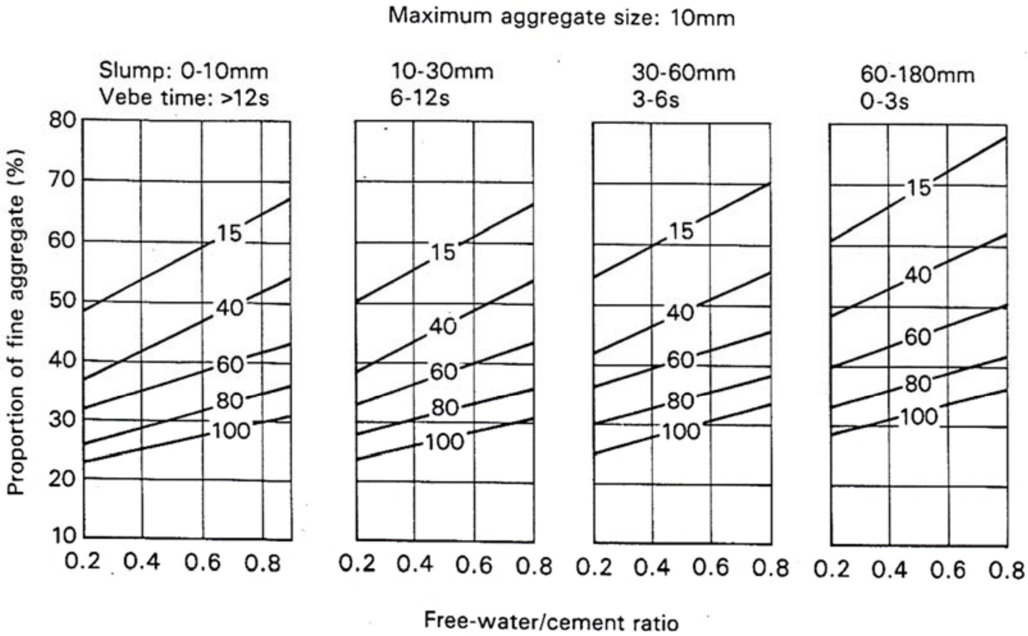

Figure 6 Recommended proportions of fine aggregate according to percentage passing a 600 μm sieve

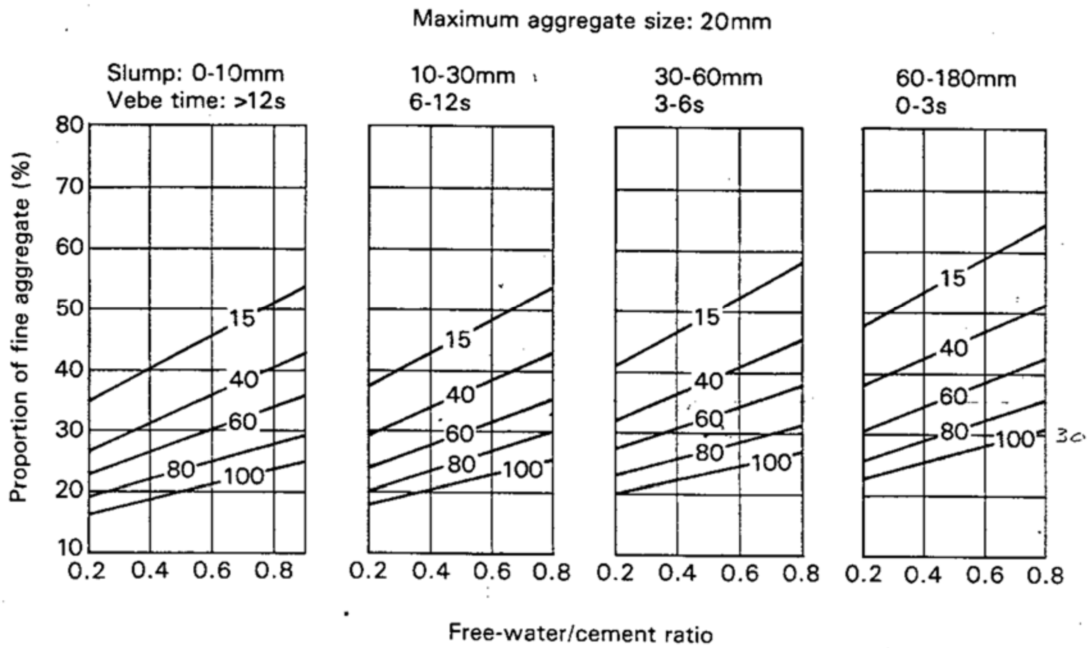

Figure 6 *(continued)*

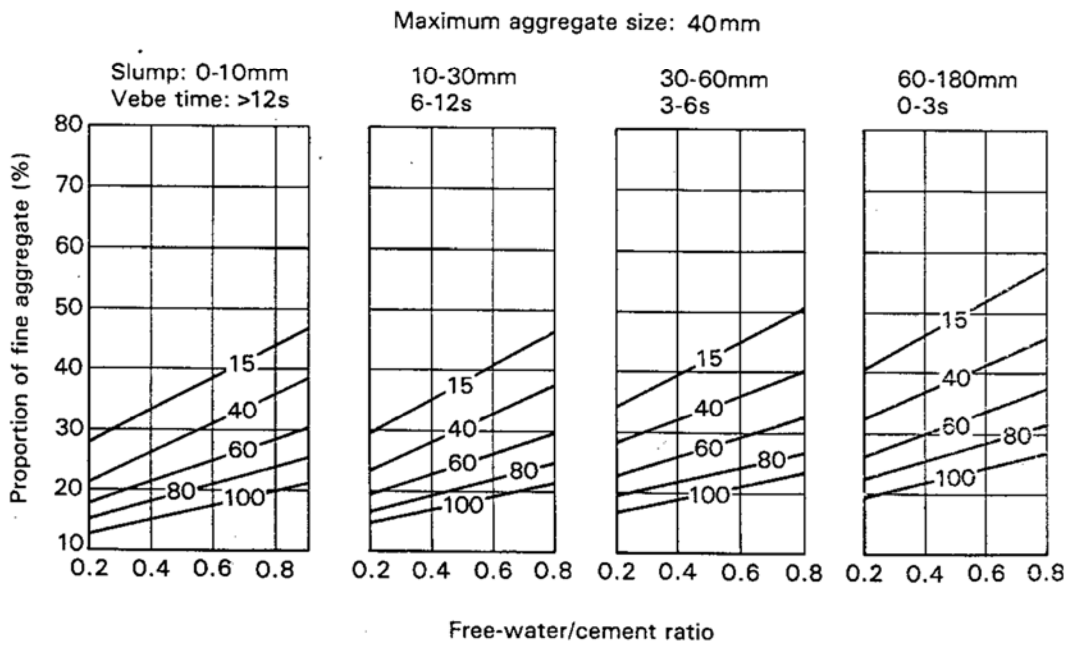

Figure 6 *(continued)*

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