UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2006/2007

April 2007

EAS 181/2 – Concrete Technology
[Teknologi Konkrit]

Duration: 2 hours
[Masa : 2 jam]

Please check that this examination paper consists of FOURTEEN printed pages including appendices before you begin the examination.
[Sila pastikan kertas peperiksaan ini mengandungi EMPAT BELAS muka surat bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]

Instructions: Answer FOUR (4) questions only. All questions carry the same marks.
*[**Arahan**: Jawab EMPAT (4) soalan sahaja. Semua soalan membawa jumlah markah yang sama.]*

You may answer the question either in Bahasa Malaysia or in English or a combination of both languages.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris ataupun kombinasi kedua-dua bahasa.]

Write the answered question numbers on the cover sheet of the answer script.
[Tuliskan nombor soalan yang dijawab di luar kulit buku jawapan anda.]

1. [a] Describe **TWO (2)** methods that could be utilized by the cement manufacturers to produce cements having different rates of strength development or heat of hydration.

(5 marks)

*Jelaskan **DUA (2)** kaedah yang boleh digunakan oleh pengilang-pengilang simen untuk menghasilkan simen yang mempunyai kadar pembentukan kekuatan atau haba penghidratan yang berbeza.*

[b] The oxide compositions of a type of Portland cement are given in Table 1. Determine the major compound compositions. Based on the compound compositions, describe the probable type of the Portland cement. Briefly explain the probable strength development characteristic, heat evolved during hydration and sulphate resistance of the Portland cement. Use the given Bogue's equations.

Komposisi oksida bagi sejenis simen Portland diberikan di dalam Jadual 1. Tentukan komposisi-komposisi sebatian utama. Berdasarkan komposisi-komposisi sebatian, jelaskan kemungkinan jenis simen Portland tersebut. Terangkan dengan ringkas kemungkinan ciri-ciri pembentukan kekuatan, haba penghidratan dan rintangan sulfat bagi simen Portland tersebut. Gunakan persamaan-persamaan Bogue yang diberikan.

Table 1: Oxide Compositions of Cement

Oxide Compositions, (%)	
CaO	61
SiO_2	24
Al_2O_3	4.6
Fe_2O_3	4.3
MgO	1.5
SO_3	1
K_2O, Na_2O}	1
Insoluble residue	0.5
Loss on ignition	1.1
Others	1

$C_3S = 4.07(CaO) - 7.60(SiO_2) - 6.72(Al_2O_3) - 1.43(Fe_2O_3) - 2.85(SO_3)$

$C_2S = 2.87(SiO_2) - 0.754(3CaO.SiO_2)$

$C_3A = 2.65(Al_2O_3) - 1.69(Fe_2O_3)$

$C_4AF = 3.04(Fe_2O_3)$

(10 markah)

1. [c] State whether the following statements regarding cement are true or false:

Nyatakan sama ada kenyataan-kenyataan berikut mengenai simen adalah betul atau salah:

(i) Gypsum (calcium sulfate) is added during the manufacturing process of cement to control the rate of early strength gain.
Gipsum (kalsium sulfat) ditambah semasa proses pengilangan simen untuk mengawal kadar peningkatan kekuatan awal.

(ii) The aluminate plays a significant role in strength development characteristics of cement.
Aluminat memainkan peranan penting didalam ciri-ciri pembentukan kekuatan simen.

(iii) C_2S hydrates more rapidly than C_3S.
C_2S menghidrat dengan lebih cepat berbanding C_3S.

(iv) The hydration of C_2S produces more C-S-H and less calcium hydroxide than that of C_3S.
Penghidratan C_2S menghasilkan lebih banyak C-S-H dan kurang kalsium hidroksida berbanding penghidratan C_3S.

(v) C_3A hydrates more rapidly than the other compounds in Portland cement.
C_3A menghidrat dengan lebih cepat berbanding sebatian-sebatian simen Portland yang lain.

(vi) A Type V Portland cement will generally have a higher C_3A content than a Type I cement.
Simen Portland Jenis V mempunyai kandungan C_3A yang lebih tinggi berbanding simen Portlang Jenis I.

(vii) A Type I Portland cement normally has smaller particle size than Type III cement.
Simen Portland Jenis I selalunya mempunyai saiz partikel yang lebih halus berbanding simen Portland Jenis III.

(viii) A Type IS Portland cements refers to Type I Portland cement containing a fix amount of ground granulated blast-furnace slag.
Simen Portland Jenis IS merujuk kepada simen Portland Jenis I yang mengandungi satu kuantiti tetap jermang relau bagas.

(ix) Production of white Portland cement utilizes high purity kaolin clay to replace normal clay.
Penghasilan simen Portland putih menggunakan tanah liat kaolin berketulenan tinggi bagi menggantikan tanah liat biasa.

(x) Portland pulverized fuel ash cement is typically used in concrete requiring less heat characteristic and good chemical resistance.
Simen Portland abu terbang selalunya digunakan untuk konkrit dengan ciri-ciri haba yang rendah dan rintangan kimia yang baik.

(10 marks)

2. [a] Using appropriate sketches, briefly describe the **FOUR (4)** probable moisture conditions of an aggregate.

(5 marks)

*Dengan menggunakan lakaran yang sesuai, jelaskan secara ringkas **EMPAT (4)** kemungkinan keadaan lembapan untuk sesuatu agregat.*

[b] Table 2 gives the grading of two samples of sand based on weight retained on the relevant sieves. Calculate the percentage of weight retained on individual sieve and the cumulative percentage retained for both samples. Display your answer in an appropriate table. From the cumulative percentage retained, determine the fineness modulus for each sand sample. Based on the fineness modulus values, explain which sand sample will require greater water content when used in concrete, assuming the quantity and characteristics of other materials used being the same.

Jadual 2 menunjukkan penggredan dua sampel pasir berdasarkan berat tertahan pada ayak-ayak yang berkaitan. Kira peratusan berat tertahan pada tiap-tiap ayak dan peratusan tertahan kumulatif bagi kedua-dua sampel. Tunjukkan jawapan anda menggunakan jadual yang sesuai. Dari peratusan tertahan kumulatif, tentukan modulus kehalusan untuk tiap-tiap sampel pasir. Berdasarkan nilai modulus kehalusan, terangkan sampel pasir yang mana akan memerlukan kandungan air yang tinggi bila digunakan didalam konkrit, dengan anggapan kandungan dan ciri-ciri bahan yang lain adalah sama.

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	0	63.1
1.18 mm	2.7	137.0
600 μm	10.1	112.1
300 μm	259.2	84.9
150 μm	173.1	48.8
Pan	8.9	9.1
Total	454	455

(20 marks)

3. [a] Give the appropriate definition of "pozzolan".

(5 marks)

Berikan takrifan yang sesuai untuk "pozzolan".

[b] The use of silica fume and metakaolin is normally associated with increase water demand of concrete. Explain how this phenomenon occurs and state one method to overcome this problem.

(5 marks)

Penggunaan wasap silika dan metakaolin selalunya dikaitkan dengan peningkatan keperluan air konkrit. Terangkan bagaimana fenomena ini berlaku dan nyatakan satu kaedah untuk menyelesaikan masalah ini.

[c] Consider the following mix proportions in kg/m^3:
Mix A: cement: 370, water: 185, river sand: 740, granite: 1120
Mix B: cement: 200, fly ash: 170, water: 185, river sand: 740, granite: 1120

Briefly explain:

(i) Which mix will have higher 7th day strength?
(ii) Which mix will have higher 1 year strength?
(iii) Which mix will be more suitable for construction of a dam?
(iv) Which mix will have higher workability?
(v) Which mix will be more expensive?

(15 marks)

Pertimbangkan nisbah campuran berikut didalam kg/m^3:
Campuran A: simen: 370, air: 185, pasir sungai: 740, granit: 1120
Campuran B: simen: 200, abu terbang: 170, air: 185, pasir sungai: 740, granit: 1120

Terangkan dengan ringkas:

(i) Campuran mana akan mempunyai kekuatan 7 hari yang tinggi?
(ii) Campuran mana akan mempunyai kekuatan 1 tahun yang tinggi?
(iii) Campuran mana lebih sesuai untuk pembinaan empangan?
(iv) Campuran mana akan mempunyai kebolehkerjaan yang lebih tinggi?
(v) Campuran mana adalah lebih mahal?

4. [a] Using the guideline on "Design of Normal Concrete Mixes" (BRE Report, 1988 given in the attachment) and based on the data given below, determine the quantity of materials for a trial mix of 0.08 m^3. **Include the attachment used with your answer script.**

Characteristic strength: 40 MPa at 28 days
Proportion defective: 5 %
Standard deviation: 5 MPa
Cement type: Ordinary Portland cement
Aggregate type (coarse): Granite;
Aggregate type (fine): River sand
Maximum free water/cement ratio: 0.45
Slump: 60 -180 mm
Maximum aggregate size: 20 mm
Relative density of aggregate (SSD): 2.7
Percentage passing 600 μm sieve: 60 %

(20 marks)

Dengan menggunakan kaedah rekabentuk campuran untuk konkrit biasa (BRE Report, 1988 seperti di Lampiran) dan berdasarkan kepada data-data yang diberikan di bawah, tentukan kuantiti bahan-bahan untuk satu campuran cubaan dengan isipadu 0.08 m^3. ***Sertakan lampiran yang digunakan bersama kertas jawapan anda.***

Kekuatan ciri: 40 MPa at 28 days
Peratus kecacatan: 5 %
Sisihan Piawai: 5 MPa
Jenis simen: Simen Portland biasa
Jenis agregat (Agregat kasar): Batuan granit
Jenis agregat (Agregat halus): Pasir sungai
Nisbah air/simen bebas maksima: 0.45
Penurunan: 60 – 180 mm
Saiz maksima agregat: 20 mm
Ketumpatan relatif agregat (SSD): 2.7
Peratusan pasir melepasi ayak 600 μm: 60 %

[b] If the sand used in (a) is moist with moisture content of 1.75% and the granite coarse aggregate is dry with water absorption of 0.8%, determine the mix proportions for 1m^3 and for the trial mix of 0.08m^3.

(5 marks)

Sekiranya pasir yang digunakan di (a) adalah lembap dengan kandungan lembapan 1.75% dan agregat kasar granit yang digunakan adalah kering dengan penyerapan air 0.8%, tentukan nisbah bancuhan untuk 1m^3 dan untuk campuran cubaan 0.08m^3.

5. [a] Explain the importance of workability and state **TWO (2)** methods that can be used to assess the workability of concrete.

(5 marks)

*Terangkan kepentingan kebolehkerjaan dan nyatakan **DUA (2)** kaedah yang boleh digunakan untuk menganggar kebolehkerjaan konkrit.*

[b] Give the appropriate definition of curing and explain the importance of curing.

(5 marks)

Berikan takrifan yang sesuai untuk pengawetan dan terangkan kepentingan pengawetan.

[c] Two concrete mixes A and B have been subjected to different curing regimes immediately after demoulding. Mix A has been continuously cured in water maintained at 20°C, while Mix B has been subjected to high temperature curing. Using an appropriate graph, briefly explain the probable different in strength development of both concrete mixes, if the mix proportions for both mixes being the same.

(5 marks)

Dua campuran konkrit A dan B telah didedahkan kepada keadaan pengawetan yang berbeza sebaik-baik sahaja dikeluarkan dari acuan. Campuran A diawet di dalam air pada suhu 20°C, manakala campuran B diawet pada suhu tinggi. Dengan menggunakan geraf yang sesuai, terangkan secara ringkas kemungkinan perbezaan pembentukan kekuatan bagi kedua-dua campuran konkrit, sekiranya nisbah campuran bagi kedua-duanya adalah sama.

[d] State whether the following statements regarding concrete are true or false:

i) Concrete with higher degree of cohesiveness will be less prone to segregation.
Konkrit yang mempunyai kejelekitan yang tinggi tidak mudah untuk mengalami pengasingan.

ii) Concrete which bleeds more will be more prone to undergo plastic shrinkage crack.
Konkrit yang mengalami penjujuhan yang lebih akan lebih mudah mengalami retak pengecutan plastik.

iii) Concrete containing fly ash is normally less sensitive to lack of curing.
Konkrit yang mengandungi abu terbang selalunya kurang sensitif kepada kurangnya pengawetan.

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iv) Autogenous shrinkage occurs due to loss of moisture to the surrounding environment.
Pengecutan autogenous berlaku disebabkan kehilangan lembapan ke persekitaran.

v) Creep is a gradual increase in strain under a sustained constant stress.
Rayapan adalah kenaikan terikan secara perlahan disebabkan tegasan malar yang berterusan.

(5 marks)

[e] Several concrete specimens were sealed (no moisture movement) and subjected to a constant compressive stress, σ_0 from the age of t_0. The specimens were then subjected to elevated temperature at the age of t ($t > t_0$).

Beberapa spesimen konkrit telah disalut (tiada pergerakan lembapan) dan dikenakan tegasan mampatan yang malar σ_0, daripada umur t_0. Spesimen-spesimen berkenaan kemudiannya didedahkan kepada suhu yang tinggi pada umur t ($t > t_0$).

i) Write an expression for creep strain of the concrete specimens involved.

Tuliskan ungkapan yang sesuai untuk rayapan bagi spesimen-spesimen konkrit yang terlibat.

ii) If the total measured strain at the age of t, $\varepsilon = 405 \times 10^{-6}$, $\sigma_0 = 10$ N/mm^2, E = 36.8 GPa, temperature rise = 30 °C, and coefficient of thermal expansion = 13×10^{-6}/°C, determine the creep strain.

Sekiranya jumlah terikan yang diukur pada umur t, $\varepsilon = 405 \times 10^{-6}$, $\sigma_0 = 10$ N/mm^2, E = 36.8 GPa, kenaikan suhu = 30 °C, dan pekali pengembangan haba = 13×10^{-6}/°C, tentukan terikan rayapan.

(5 marks)

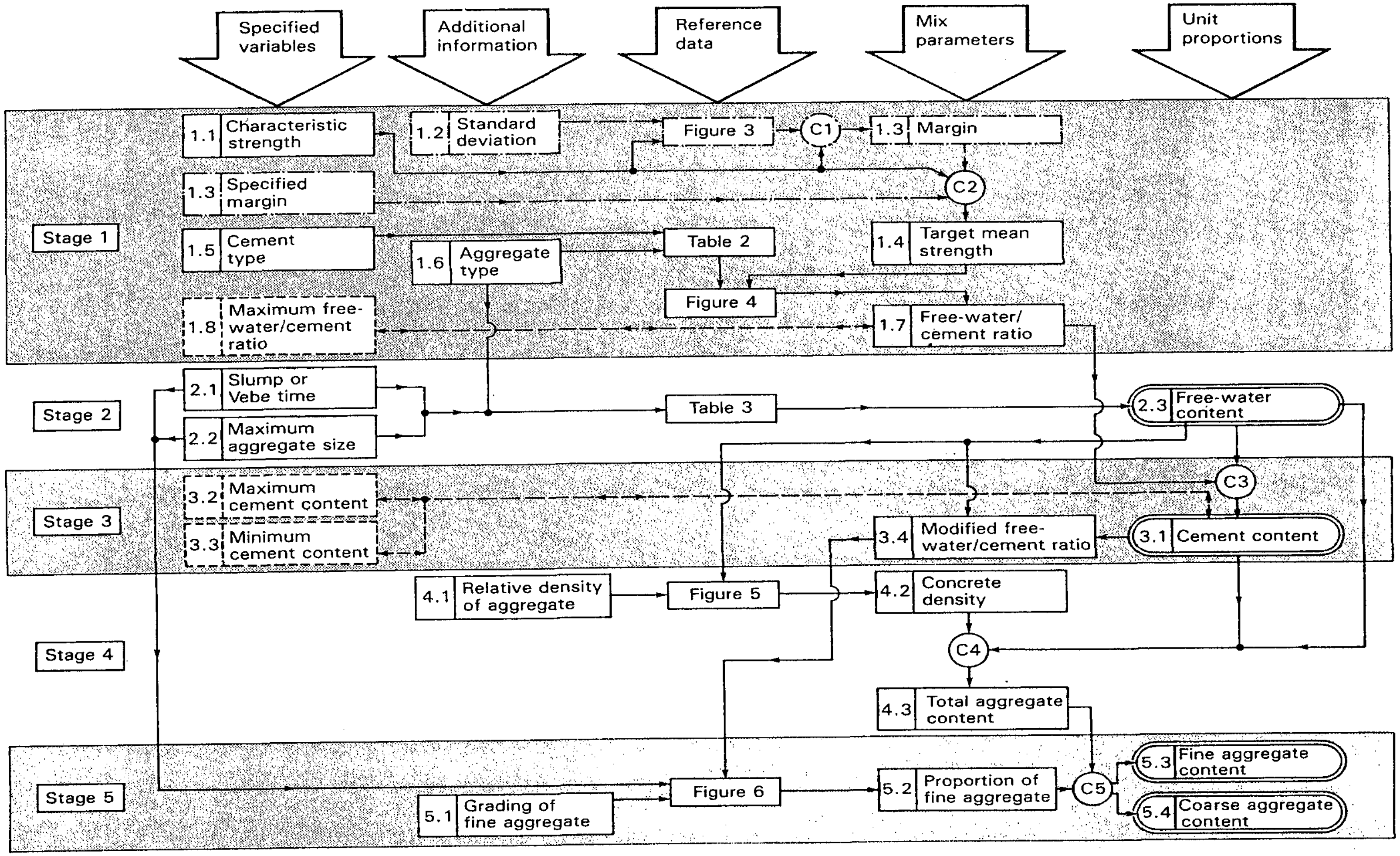

Figure 2 Flow chart of mix design procedure. Items in dashed boxes and with two-way arrows are optional limiting values that may be specified. C = calculation
Items in chain-dotted boxes are alternatives

Concrete mix design form

Job title ....

Stage	Item		Reference or calculation	Values
1	1.1	Characteristic strength	Specified	______ N/mm² at ______ days Proportion defective ______ %
	1.2	Standard deviation	Fig 3	______ N/mm² or no data ______ N/mm²
	1.3	Margin	C1 or Specified	(k = ______) ______ × ______ = ______ N/mm² ______ N/mm²
	1.4	Target mean strength	C2	______ + ______ = ______ N/mm²
	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/m³
3	3.1	Cement content	C3	______ ÷ ______ = ______ kg/m³
	3.2	*Maximum cement content*	*Specified*	______ kg/m³
	3.3	*Minimum cement content*	*Specified*	______ kg/m³
				use 3.1 if ≤ 3.2 use 3.3 if > 3.1 ☐ kg/m³
	3.4	Modified free-water/cement ratio		______ ☐
4	4.1	Relative density of aggregate (SSD)		______ known/assumed
	4.2	Concrete density	Fig 5	______ kg/m³
	4.3	Total aggregate content	C4	______ − ______ − ______ = ______ kg/m³
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/m³
	5.4	Coarse aggregate content	C5	______ − ______ = ☐ kg/m³

Quantities	Cement (kg)	Water (kg or *L*)	Fine aggregate (kg)	Coarse aggregate (kg) 10 mm	20 mm	40 mm
per m³ (to nearest 5 kg)	______	______	______	______	______	______
per trial mix of ______ m³	______	______	______	______	______	______

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

1 N/mm² = 1 MN/m² = 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) / Vebe time(s)		0-10 / >12	10-30 / 6-12	30-60 / 3-6	60-180 / 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:

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

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:

Total aggregate content $= D - C - W$ ...*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.

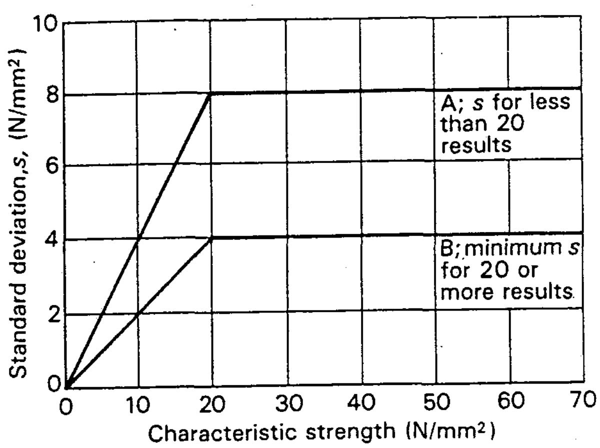

Figure 3 Relationship between standard deviation and characteristic strength

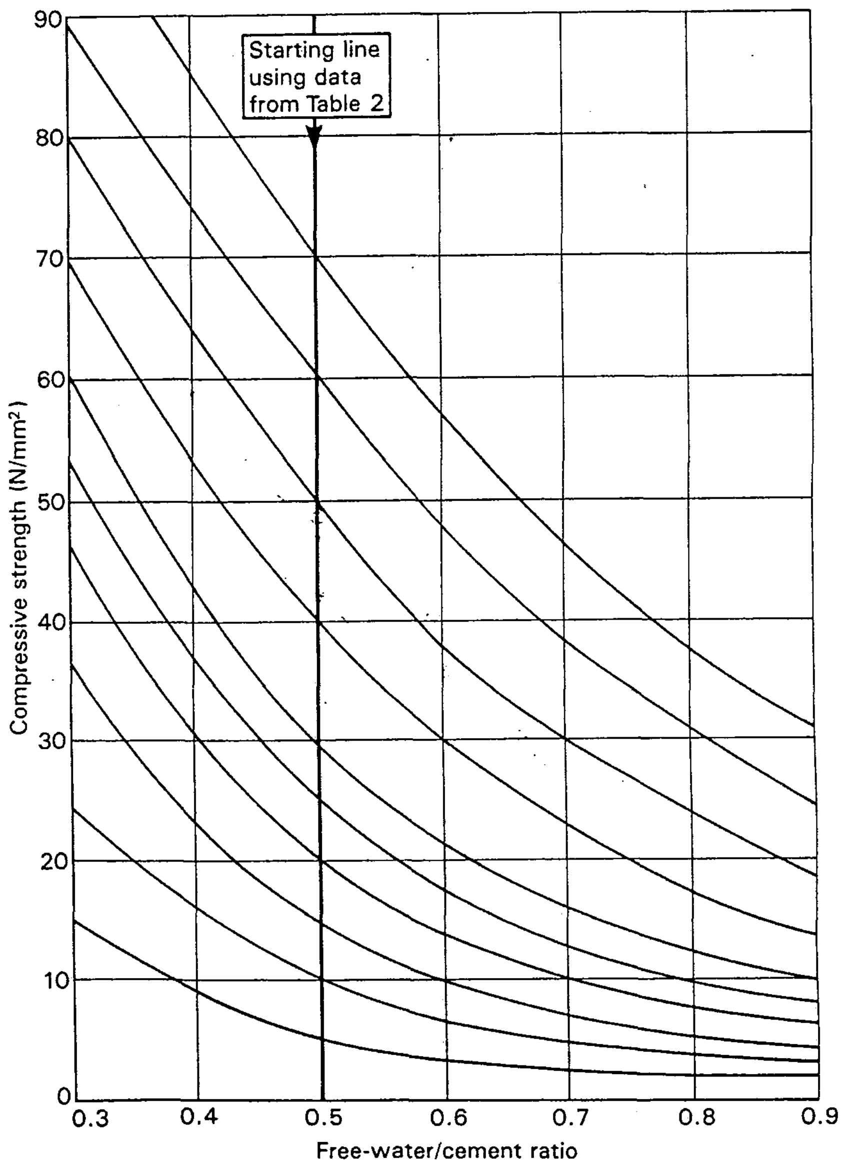

Figure 4 Relationship between compressive strength and free-water/cement ratio

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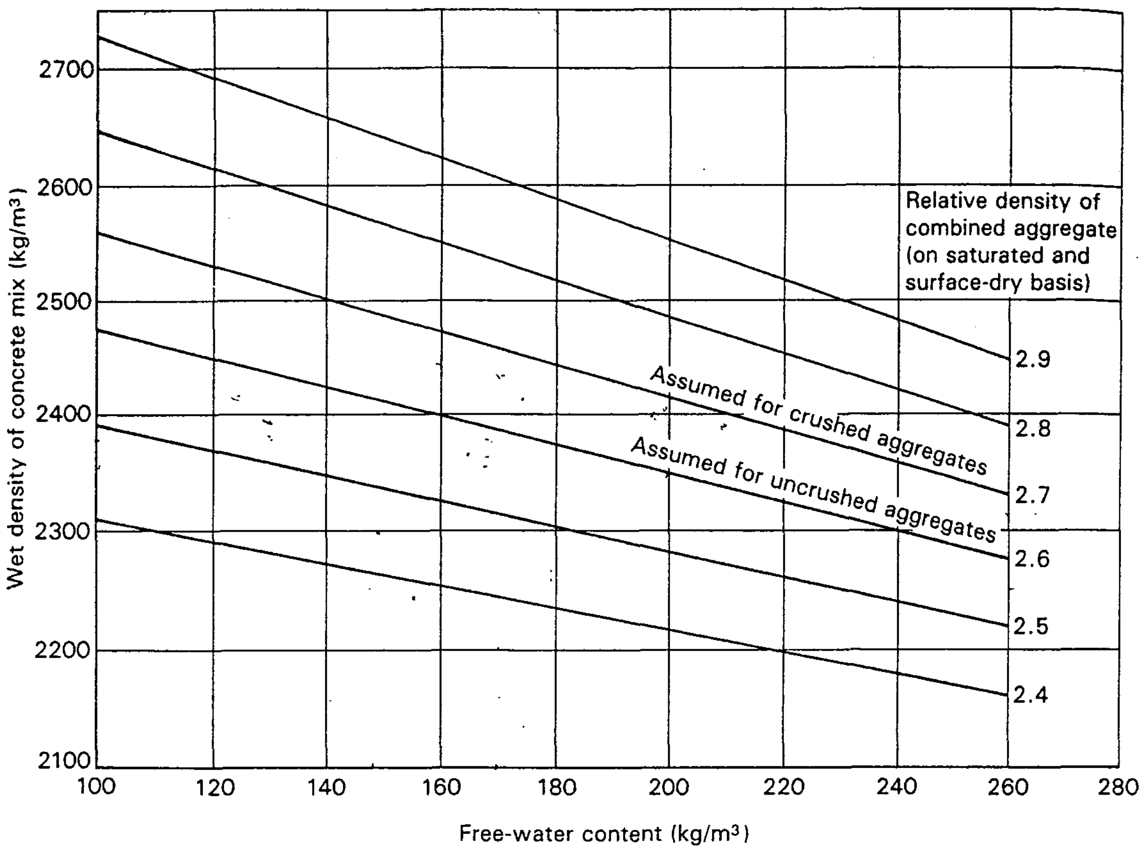

Figure 5 Estimated wet density of fully compacted concrete

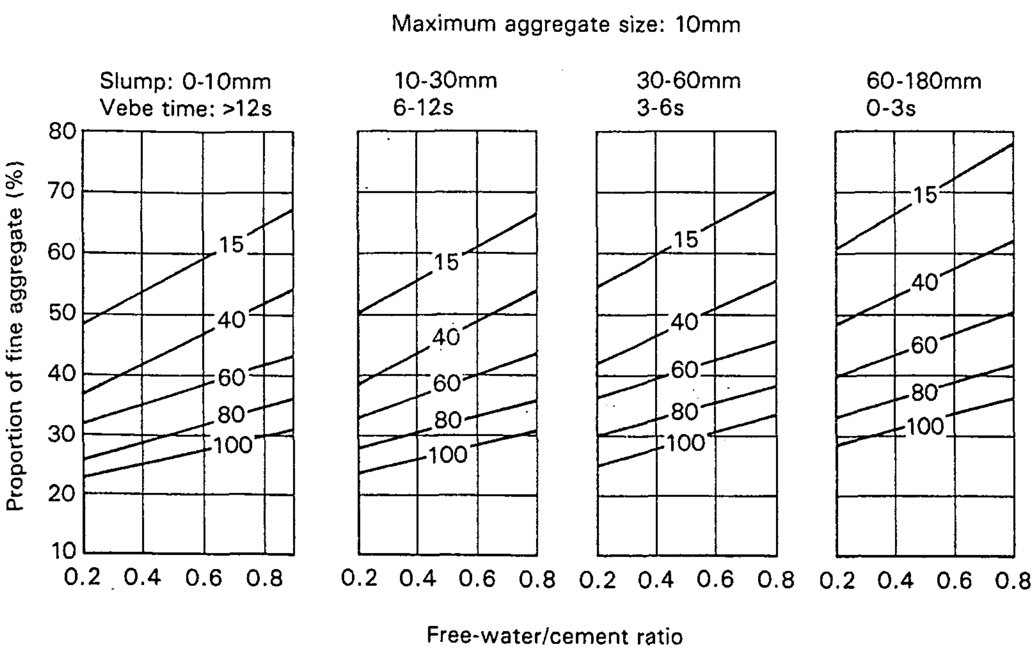

Figure 6 Recommended proportions of fine aggregate according to percentage passing a 600 μm sieve

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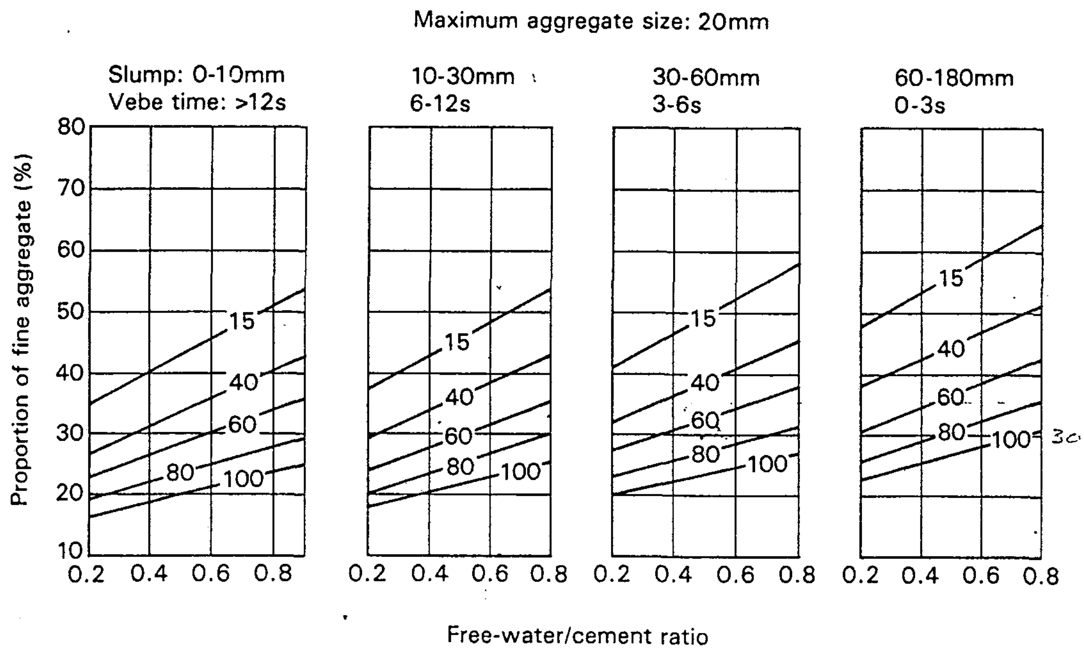

Figure 6 *(continued)*

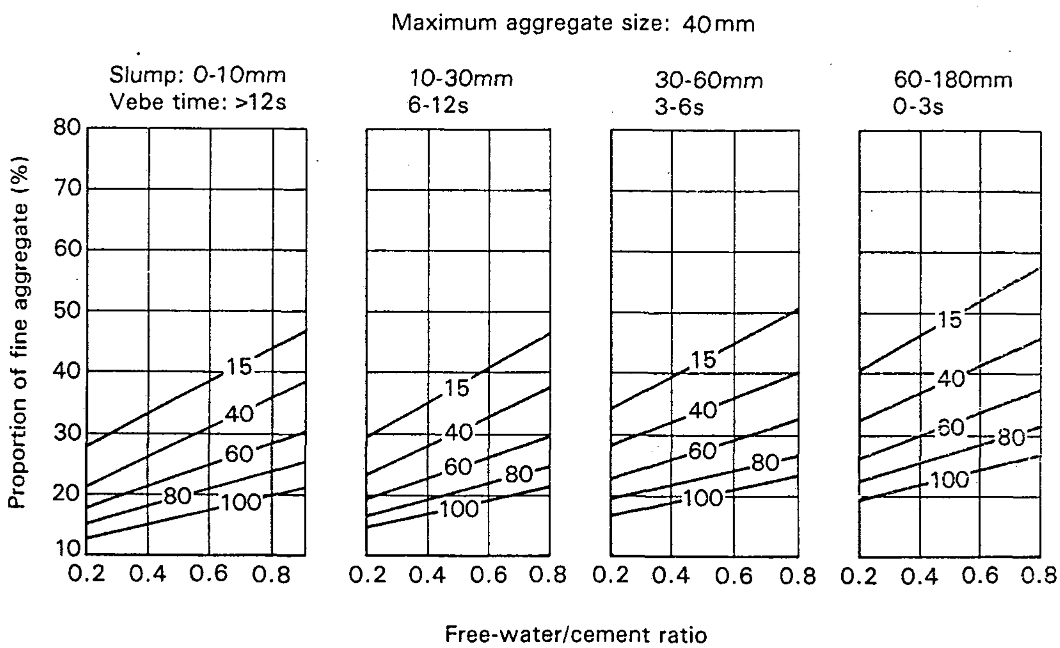

Figure 6 *(continued)*