First published, March 1992
Reprinted, April 1993 Second reprint, March 1994
Third reprint, July 1995 Fourth reprint, August 1996
Fifth reprint, December 1997 Sixth reprint, November 1998
Seventh reprint with amendments promulgated under Corrigendum Nos. 1/93, 1/94, 2/94, 1/95, 1/96, 2/96, 1/97, 2/97, 1/98, 2/98, 1/99, 2/99 and 1/2000 incorporated, March 2001
Eighth reprint with all amendments incorporated in the seventh reprint and with amendments promulgated under Corrigendum Nos. 1/2001, 2/2001, 3/2001, 1/2002 and 2/2002 incorporated, October 2002

Prepared by:

Standards Unit,
Civil Engineering Department,
Civil Engineering Building,
101 Princess Margaret Road,
Homantin, Kowloon,
Hong Kong.

Steering Committee members:

R.H. Pilling (Chairman)

C.L. Au	C.K. Au Yong	W.S. Chan
T.K. Cheung	D.J. Howells	T.L. Hsu
H.S. Kwong	I.M. Miller	K.P. Mok
H. Sanders	K.Y. Tang	H.S. Tse

This publication is available from:

Government Publications Centre,
Ground Floor, Low Block,
Queensway Government Office,
66 Queensway,
Hong Kong.

Future amendments of this publication will be published on the website of the Civil Engineering Department at http://www. info.gov.hk/ced/.

Overseas orders should be placed with:

Publications Sales Section,
Information Services Department,
Room 402, 4th Floor, Murray Building,
Garden Road, Central,
Hong Kong.

Price in Hong Kong: HK$173.00 (in set of 3 volumes)
Price overseas: US$33.00 (including surface postage)

An additional bank charge of **HK$50** or **US$6.50** is required per cheque made in currencies other than Hong Kong dollars.

Cheques, bank drafts or money orders must be made payable to
The Government of the Hong Kong Special Administrative Region.

FOREWORD

This Specification lays down the quality of materials, the standards of workmanship, the testing methods and the acceptance criteria for civil engineering works undertaken for the Hong Kong Government. It supersedes "Public Works Department, Civil Engineering Office and Highways Office General Specification for Civil Engineering Works, 1977 Edition" and "Water Supplies Department, General Specification for Civil Engineering Works, 1987 Edition".

The Specification is to be cited as "General Specification for Civil Engineering Works, 1992 Edition (Hong Kong Government)". It is compatible with "General Conditions of Contract for Civil Engineering Works, 1990 Edition (Hong Kong Government)" and "Standard Method of Measurement for Civil Engineering Works, 1992 Edition (Hong Kong Government)". Where necessary, it should be supplemented by a particular Specification.

This new Specification was produced over a six-year period under the guidance of a Steering Committee which comprised members from all the main Government departments concerned with the execution of civil engineering works. The drafting of each Section was carried out by a Working party consisting of individuals who possessed the appropriate knowledge and expertise. Drafts of the Sections were circulated for comment inside and outside the Government before finalization. The published document therefore takes account of recent technological advances and their application to civil engineering works in Hong Kong. The overall co-ordination for the document, and its final editing and production, were the responsibility of the Standards Unit of the Civil Engineering Department.

March 1992

GENERAL SPECIFICATION FOR CIVIL ENGINEERING WORKS

CONTENTS

VOLUME 1

VOLUME 2

VOLUME 3

CONTENTS OF VOLUME 2

SECTION 9

CARRIAGEWAYS: SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

Page No.

TESTING: SURFACE REGULARITY

TESTING: SUB-BASE MATERIAL

TESTING: RELATIVE COMPACTION OF SUB-BASE

TESTING: AGGREGATES, FILLER AND BITUMEN FOR BITUMINOUS MATERIALS

TESTING: BITUMINOUS MATERIALS OTHER THAN BITUMINOUS FRICTION COURSE MATERIAL

TESTING: BITUMINOUS FRICTION COURSE MATERIAL

SECTION 10

CONCRETE CARRIAGEWAYS

GENERAL

MATERIALS

SECTION 11

MISCELLANEOUS ROADWORKS

PART 1: GENERAL REQUIREMENTS

GENERAL

SECTION 12

TRAFFIC SIGNS, ROAD MARKINGS AND ROAD STUDS

PART 1 : TRAFFIC SIGNS

GENERAL

MATERIALS

FABRICATION OF TRAFFIC SIGNS

SUBMISSIONS

STORAGE OF MATERIALS

SECTION 14

FORMWORK AND FINISHES TO CONCRETE

GENERAL

GLOSSARY OF TERMS

MATERIALS

SECTION 15

STEEL REINFORCEMENT

GLOSSARY OF TERMS

MATERIALS

SECTION 16

CONCRETE AND JOINTS IN CONCRETE

PART 1: CONCRETE WORKS

GENERAL

GLOSSARY OF TERMS

MATERIALS

CONCRETE

Page No.

APPENDIX 16.3

DETERMINATION OF THE RECOVERY VALUE, REDUCTION IN MASS AND THE EXTRUSION OF JOINT FILLER

SECTION 17

PRESTRESSING

GENERAL

GLOSSARY OF TERMS

MATERIALS

SUBMISSIONS

Page No.

TESTING: GROUT – CRUSHING STRENGTH

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 9

CARRIAGEWAYS: SUB-BASE MATERIAL AND

BITUMINOUS MATERIALS

SECTION 9

CARRIAGEWAYS: SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

GLOSSARY OF TERMS

Nominal maximum aggregate size 9.01 Nominal maximum aggregate size is the smallest BS sieve size for which the upper limit of the percentage of the aggregate by mass passing is 100%.

MATERIALS

Sub-base material 9.02 Sub-base material shall be crushed rock and shall have the properties stated in Table 9.1. Sub-base material passing the 425 μm BS test sieve, when tested in accordance with Clause 9.43(4) shall be non-plastic.

Table 9.1: Properties of sub-base material

Properties	BS test sieve	Percentage by mass passing
Particle size distribution	75 mm 37.5 mm 20 mm 10 mm 5 mm 600 μm 75 μm	100 85 - 100 60 - 85 40 - 70 25 - 45 8 - 22 0 - 10
Ten percent fines value		> 50 kN

Aggregates for bituminous materials 9.03 (1) Coarse aggregate for bituminous materials shall be crushed rock all retained on a 5 mm BS test sieve and shall have the properties stated in Table 9.2.

(2) Fine aggregate for bituminous materials shall be crushed rock, river sand or a mixture of crushed rock and river sand all passing 5 mm BS test sieve. The water absorption of fine aggregate shall not exceed 2.0%.

(3) For the purpose of mix design, the combined grading of aggregates for bituminous materials shall be such that the particle size distribution lies within the limits stated in Table 9.3 for the relevant bituminous material.

Table 9.2: Properties of coarse aggregate for bituminous materials

Properties	Nominal maximum aggregate size (mm)			
	37.5	28	20	10
Flakiness index	≤ 25.0%	≤ 26.0%	≤ 27.0%	≤ 30.0%
Ten percent fines value	> 100 kN			
Water absorption	≤ 2.0%			

Table 9.3: Design limits for particle size distribution and bitumen content for bituminous materials

Properties		Type of bituminous material					
		Roadbase (recipe mix)	Base course		Wearing course		Friction course
Nominal maximum aggregate size (mm)		37.5	37.5	28	20	10	10
Particle size distribution	BS test sieve	Percentage by mass passing					
	50 mm	100	100	-	-	-	-
	37.5 mm	90 - 100	91 - 100	100	-	-	-
	28 mm	70 - 94	70 - 94	91 - 100	100	-	-
	20 mm	62 - 84	62 - 84	85 - 95	91 - 100	-	-
	14 mm	-	55 - 76	72 - 87	78 - 90	100	100
	10 mm	49 - 67	49 - 67	55 - 75	68 - 84	87 - 100	85 - 100
	5 mm	37 - 55	37 - 55	35 - 53	54 - 72	62 - 80	20 - 40
	2.36 mm	27 - 43	27 - 43	25 - 40	42 - 58	42 - 58	5 - 15
	1.18 mm	-	20 - 35	15 - 30	34 - 48	34 - 48	-
	600 µm	13 - 28	13 - 28	12 - 24	24 - 38	24 - 38	-
	300 µm	7 - 21	7 - 21	8 - 18	16 - 28	16 - 28	-
	150 µm	-	4 - 14	5 - 12	8 - 18	8 - 18	-
	75 µm	2 - 8	2 - 8	3 - 6	4 - 8	4 - 8	2 - 6
Bitumen content as percentage of total mass including binder	min.	3.0	4.0	4.5	5.0	6.0	4.5
	max.	4.0	4.5	5.0	5.5	7.0	5.5

Filler for bituminous materials 9.04 (1) Filler for bituminous materials shall be crushed rock filler, OPC, PPFAC, PFA or hydrated lime. Filler shall be free-flowing and dry before addition to the bituminous mixture.

(2) Filler for bituminous friction course material shall contain hydrated lime; the amount of hydrated lime, expressed as a percentage by mass of the total aggregates, shall be at least 1.5%.

(3) OPC shall comply with BS 12. PPFAC shall comply with BS 6588.

(4) PFA shall comply with BS 3892: Part 1 except that the criterion for maximum water requirement shall not apply.

(5) Crushed rock filler and hydrated lime shall comply with ASTM D 242.

Bitumen 9.05 Bitumen for bituminous materials shall comply with ASTM D 946, Grade 60-70 and shall have a softening point exceeding 44°C and less than 55°C. Unless otherwise permitted by the Engineer, blending or mixing of bitumen shall be carried out at a refinery approved by the Engineer.

Bituminous emulsion 9.06 Bituminous emulsion shall be anionic bituminous emulsion complying with BS 434: Part 1, Table 1, Class A1-40 or cationic bituminous emulsion complying with BS 434: Part 1, Table 2, Class K1-40.

Bituminous priming material 9.07 Bituminous priming material shall be medium curing-grade cutback bitumen complying with ASTM D 2027, Table 1, Class MC-30.

DESIGN OF SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

Design procedure for sub-base material and bituminous materials 9.08 (1) Sub-base material and bituminous roadbase materials shall be recipe mixes. Laboratory design mixes other than those for sub-base material and bituminous roadbase materials shall be made and tested as part of the design procedure at a laboratory approved by the Engineer.

(2) Unless otherwise permitted by the Engineer, mix designs and associated tests shall be carried out by the Contractor in the presence of the Engineer. The Contractor shall notify the Engineer at least 7 days, or such shorter period agreed by the Engineer, before carrying out the mix designs.

Design of bituminous materials 9.09 (1) Bituminous materials shall consist of coarse and fine aggregates complying with Clause 9.03, filler complying with Clause 9.04 and bitumen complying with Clause 9.05. The different types of bituminous materials shall have particle size distributions and bitumen contents within the limits stated in Table 9.3.

(2) The properties of the different types of bituminous materials shall be as stated in Table 9.4.

(3) Bituminous materials of all aggregate sizes, other than bituminous roadbase material, shall be designed in accordance with the Marshall Method of Mix Design stated in The Asphalt Institute Handbook `MS-2 Mix Design Methods for Asphalt Concrete and other Hot-mix Types,' 1984 with modifications only if agreed by the Engineer. The compaction standard shall be 75 blows per side.

(4) Design procedures for bituminous friction course material shall be as stated in Clause 9.09(3) except that the mixing and compaction temperatures shall be consistent with bitumen viscosities of 900 ± 100 centistokes and 2000 ± 200 centistokes respectively.

Table 9.4: Properties of designed bituminous materials

Properties	Type of bituminous material				
	Base course		Wearing course		Friction course
	Nominal maximum aggregate size (mm)				
	37.5	28	20	10	10
Minimum Marshall stability (kN)	10.0		10.0		-
Maximum flow value (mm)	4.0		4.0		-
Minimum voids in mineral aggregate as a percentage of total bulk volume	12.5	13.0	14.0	16.0	25.0
Air voids in mix as a percentage of total bulk volume	3.0 - 5.0		3.0 - 5.0		18.0 - 25.0

SUBMISSIONS

Particulars of filler and bitumen for bituminous materials

9.10 (1) The following particulars of the proposed filler and bitumen for bituminous materials shall be submitted to the Engineer:

(a) a certificate from the manufacturer for each type of filler showing the manufacturer's name, the date and place of manufacture and showing that the filler complies with the requirements stated in the Contract and including results of tests for particle size distribution, and

(b) a certificate from the manufacturer for bitumen showing the manufacturer's name, the date and place of manufacture and showing that the bitumen complies with the requirements stated in the Contract, including a temperature-viscosity relationship for the bitumen, and including results of tests for:
- relative density
- softening point
- penetration
- ductility
- retained penetration after thin film oven test
- solubility
- viscosity
- loss on heating.

(2) The particulars, including certificates, shall be submitted to the Engineer at the time stated in Clause 9.11(3).

(3) Further certificates showing that the materials comply with the specification shall be submitted at intervals agreed by the Engineer.

Particulars of mixes for sub-base material and bituminous materials

9.11 (1) The following particulars of sub-base material and bituminous roadbase materials shall be submitted to the Engineer:

(a) source and type of aggregates,

(b) grading details in tabular and graphical form, and

(c) details of each mixing plant proposed,

(2) The following particulars of bituminous materials shall also be submitted to the Engineer:

(a) certified copies of work sheets for mix designs, which shall include the relative density of the mixed aggregates,

(b) source of bitumen, and

(c) If requested by the Engineer, past test records of the same mix produced in the same plant.

(3) The particulars shall be submitted to the Engineer at least 21 days before:

(a) trial areas are constructed, or

(b) the mix is placed in the permanent work if trial areas are not required.

Particulars of supplier of sub-base material and bituminous materials

9.12 The name of the supplier and the location of each plant from which the Contractor proposes to obtain sub-base material and bituminous materials shall be submitted to the Engineer at the time stated in Clause 9.11(3).

Particulars of methods of laying and compacting sub-bases and bituminous materials

9.13 (1) The following particulars of the proposed methods of laying and compacting sub-bases and bituminous materials shall be submitted to the Engineer:

(a) details of Constructional Plant, and

(b) programme and rate of working.

(2) The particulars shall be submitted to the Engineer at the time stated in Clause 9.11(3).

Samples of sub-base material, aggregate, filler and bitumen

9.14 One sample of each type of sub-base material and one sample of each type of aggregate, filler and bitumen for bituminous material shall be submitted to the Engineer at the same time as particulars are submitted.

TRIALS

Trial areas

9.15 (1) Trial areas of each type and layer of bituminous materials shall be constructed to demonstrate that the proposed materials, mixes, methods of production and methods of construction are capable of producing a carriageway which complies with the specified requirements. Unless otherwise stated in the Contract, the trial areas shall be constructed as part of the permanent carriageway at locations agreed by the Engineer. The width of each trial area shall be at least one lane of carriageway, and the length shall be at least 60 m.

(2) Trial areas shall be constructed using the materials, mixes, methods of production and methods of construction submitted to the Engineer. Materials shall be delivered in not less than two loads.

(3) The Contractor shall inform the Engineer 48 hours, or such shorter period agreed by the Engineer, before constructing trial areas.

(4) The permission of the Engineer shall be obtained before each layer of material is placed in the trial area.

(5) The Engineer shall be given sufficient time to determine whether the specified requirements have been produced in the trial area before further material of the same type is placed in the permanent carriageway.

(6) Trial areas shall be protected from damage and shall be left in position unless the Engineer instructs their removal. Trial areas which form part of the permanent carriageway and which comply with the specified requirements shall not be removed.

Table 9.5: Sampling and testing bituminous materials

Type of material	Properties	Methods of sampling	Methods of testing
Bituminous base course and wearing course material	Particle size distribution	Clause 9.51	Clause 9.52
	Bitumen content	Clause 9.51	Clause 9.52
	Rice's specific gravity	Clause 9.51	Clause 9.52
	Void content	Clause 9.58	Clause 9.59
Bituminous friction course material	Particle size distribution	Clause 9.55	Clause 9.56
	Bitumen content	Clause 9.55	Clause 9.56
	Texture depth and permeability	-	Clause 9.62

Samples: trial areas 9.16 (1) One sample of bituminous materials, excluding bituminous roadbase materials, shall be provided from each mix used in trial areas. The method of sampling shall be as stated in Table 9.5.

(2) Ten cores shall be cut from each layer of base course and wearing course in trial areas. The method of taking cores shall be as stated in Clause 9.58.

Testing: trial areas 9.17 (1) Each sample of bituminous material taken as stated in Clause 9.16, shall be tested to determine the properties stated in Table 9.5. The method of testing shall be as stated in Table 9.5.

(2) If the layer is to form part of the permanent work, each layer of bituminous material in trial areas, excluding bituminous roadbase material, shall be tested as stated in Clause 9.37 to determine the level of the surface.

(3) The layer which is to be the final layer of the carriageway in each trial area shall be tested as stated in Clauses 9.39 and 9.40 to determine the surface regularity, if the layer is to form part of the permanent work.

(4) The layer of friction course in each trial area shall be tested as stated in Clauses 9.62 to 9.64 to determine the texture depth and permeability.

(5) Cores shall be tested as stated in Clauses 9.58 to 9.61 to determine the compacted layer thickness and air void content.

Compliance criteria: trial areas 9.18 The properties of the materials, the levels of the surface, compaction, surface regularity, texture depth and permeability of bituminous materials laid in the trial areas shall comply with the specified requirements for the permanent carriageway.

Non-compliance: trial areas 9.19 (1) If the result of any test on trial areas does not comply with the specified requirements for trial areas, particulars of proposed changes to the materials, mixes, methods of production or methods of construction shall be submitted to the Engineer; further trial areas shall be constructed until the result of every test on trial areas complies with the specified requirements for the trial areas.

(2) Unless otherwise permitted by the Engineer, trial areas, or parts of trial areas, which do not comply with the specified requirements for the trial area shall be removed.

Approved mix for bituminous materials other than bituminous roadbase material

9.20 (1) A mix for bituminous materials other than bituminous roadbase material which complies with the specified requirements for designed mixes and for trial areas shall become an approved mix.

(2) The approved gradation envelope for bituminous materials other than bituminous roadbase material shall be the gradation envelope found by applying the tolerances stated in Table 9.6 to the particle size distribution of the approved mix.

(3) The approved bitumen content range for bituminous materials other than bituminous roadbase material shall be the bitumen content range formed by applying a tolerance of ±0.5% to the bitumen content of the approved mix.

Table 9.6: Tolerances for particle size distribution from approved mix

BS test sieve	Tolerance of particle size distribution in percentage by mass of total mix passing BS test sieve			
	Nominal maximum aggregate size (mm)			
	37.5	28	20	10
50 mm	0	-	-	-
37.5 mm	± 4	0	-	-
28 mm	± 7	± 4	0	-
20 mm	± 7	± 7	± 4	-
14 mm	± 7	± 7	± 7	0
10 mm	± 7	± 7	± 7	± 4
5 mm	± 7	± 7	± 7	± 7
2.36 mm	± 7	± 7	± 7	± 7
1.18 mm	± 7	± 7	± 7	± 7
600 μm	± 5	± 5	± 5	± 5
300 μm	± 5	± 5	± 5	± 5
150 μm	± 3	± 3	± 3	± 3
75 μm	± 2	± 2	± 2	± 2

Commencement of placing bituminous materials

9.21 Bituminous material shall not be placed in the permanent work until the mix has been approved by the Engineer.

Changes in materials and methods of construction

9.22 Unless permitted by the Engineer, the materials and methods of production used in producing the approved mixes and the methods of construction used in trial areas shall not be changed.

HANDLING, STORAGE AND TRANSPORT OF MATERIALS

Handling and storage of sub-base material and bituminous materials

9.23 (1) Cement and PFA shall be stored as stated in Clause 16.33.

(2) Sub-base material and bituminous materials shall not be handled or stored in a manner which will result in mixing of the different types and sizes or in segregation or contamination of the materials.

(3) Unless otherwise permitted by the Engineer, bituminous materials shall not be stored in heated surge bins for more than 12 hours or in transport vehicles for more than 3 hours.

(4) Bituminous friction course material shall not be stored in surge bins for more than 30 minutes.

Transport of sub-base material and bituminous materials

9.24 (1) Sub-base material and bituminous materials shall be protected by covers while being transported and before laying. Covers for bituminous materials shall be heavy canvas or a similar insulating material; the covers shall completely cover the material and shall be securely fixed to minimise loss of heat and to protect the materials from contamination by dust or other deleterious material.

(2) Sub-base material and bituminous materials shall be transported in clean vehicles with smooth trays and sides.

(3) The trays of vehicles transporting bituminous materials may be lubricated with soap solution or light oil sprayed on the trays. Vehicles transporting bituminous friction course material shall not be lubricated with light oil.

MIXING OF SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

Mixing of sub-base material and bituminous materials

9.25 Mixing of sub-base material and mixing of bituminous materials shall be carried out before delivery to the Site at mixing plants approved by the Engineer. The plants shall be designed and operated to produce uniform mixes which comply with the specified requirements.

Mixing plant for bituminous materials

9.26 (1) The mixing plant for bituminous materials shall have at least four separate cold feed bins for preliminary cold batching of the coarse and fine aggregates, and a rotary drum dryer which will continuously agitate the aggregates during the heating and drying processes. After passing through the dryer, the aggregates shall be screened into at least four hot storage bins before mixing.

(2) Bitumen heating and storage tanks shall be fitted with circulating pumps to ensure an even temperature throughout the tanks.

(3) The mixing plant shall be provided with sampling devices to enable samples of hot aggregates, filler and bitumen to be taken before mixing.

(4) Insulated surge bins, if fitted to the mixing plant, shall be designed and operated to prevent segregation occurring in the mix. Heating devices

fitted to surge bins shall be capable of maintaining the temperature of the mix to within the specified limits.

(5) Measuring and weighing equipment shall be maintained in a clean, serviceable condition. The equipment shall be set to zero daily and calibrated before mixes for the permanent work are produced, and at regular intervals not exceeding 6 months.

(6) Alternative methods of mixing bituminous materials may be used with the approval of the Engineer.

Mixing bituminous materials 9.27 (1) Aggregates and filler for bituminous materials shall be measured to an accuracy of ± 3.0% by mass. The aggregate moisture content after drying shall not exceed 0.4% by mass.

(2) Mixing of bituminous materials shall continue after the addition of all constituents for such period as is necessary to ensure that the aggregates and filler are uniformly coated with bitumen.

(3) Bituminous materials shall comply with the temperature requirements as stated in Table 9.7 during and after mixing.

Table 9.7: Temperature requirements for bituminous materials

Type of bituminous material		Roadbase, base course and wearing course	Friction course
Aggregate temperature at mixing (ºC)	Min. Max.	130 175	115 135
Binder temperature at mixing (ºC)	Min. Max.	135 165	115 165
Bituminous mixture temperature after mixing (ºC)	Min. Max.	130 165	115 135
Bituminous mixture temperature at laying (ºC)	Min. Max.	- -	110 135
Bituminous mixture temperature at start of compaction (ºC)	Min.	-	85

PRELIMINARY WORK

Installation of utilities 9.28 (1) Pipes, cables, manholes, chambers, gullies and other utilities below carriageways shall be completed and fill material shall be deposited and compacted in trenches before the carriageway is constructed. Openings to manholes, chambers and gullies shall be protected by temporary covers or by other methods agreed by the Engineer.

(2) Covers, frames and other hardware which will prevent continuous laying of bituminous materials for roadbase and base course shall not be fixed in position until such work is complete.

(3) After the penultimate layer of bituminous material has been laid and compacted, the layers of asphalt shall be cut out, temporary covers shall be removed and the permanent covers, frames and other hardware shall be installed.

(4) Finishing around covers, frames and other hardware shall be carried out using bituminous material of the same type as that in the adjacent surface unless otherwise permitted by the Engineer. The material shall be compacted in layers not exceeding 50 mm thick using hand rammers or mechanical equipment up to the underside of the wearing course or friction course.

LAYING AND COMPACTION OF SUB-BASE MATERIAL

Laying and compaction of sub-base material 9.29

(1) Sub-base material shall be laid and compacted in a manner which will not result in segregation of the material and at a moisture content which allows the compaction stated in Clause 9.29(6) to be achieved. The moisture content shall not be less than 2%.

(2) Sub-base material shall be laid in layers in such a manner that the compacted thickness of each layer will not exceed 225 mm. If the specified final compacted thickness of the sub-base exceeds 225 mm, the material shall be laid in two or more layers; the minimum thickness of each layer shall be 100 mm and, if the layers are of unequal thickness, the lowest layer shall be the thickest.

(3) Each layer of sub-base material shall be evenly spread immediately after placing in position and shall be compacted immediately after spreading.

(4) The minimum compaction plant to be used for compaction of sub-base material shall be of the type as stated in Clause 9.33(1).

(5) The permission of the Engineer shall be obtained before the next layer is placed on each layer of compacted sub-base material.

(6) Sub-base material shall be compacted to obtain a relative compaction of at least 95% maximum dry density throughout.

(7) The surface of each layer of sub-base shall be maintained in a compacted condition until the next layer of sub-base material or roadbase material is laid; the surface shall not be disturbed by Constructional Plant or other vehicles, and shall be free from ridges, cracks, loose material, pot-holes, ruts or other defects.

LAYING AND COMPACTION OF BITUMINOUS MATERIALS

Laying and compaction of bituminous materials

9.30 (1) Bituminous materials shall not be laid during periods of wet weather or when ponded water is present on the underlying surface unless in the opinion of the Engineer the works will not be adversely affected.

(2) Bituminous wearing course material shall not be laid when the ambient air temperature is below 8°C and bituminous friction course material shall not be laid when the ambient air temperature is below 10°C. Temperatures shall be measured in the shade near to the surface on which laying is to be carried out.

(3) Surfaces on which bituminous materials are laid shall be clean and free from mud, grit and other deleterious material.

(4) If instructed by the Engineer, a tack coat of bituminous emulsion shall be applied to surfaces on or against which bituminous materials will be laid. The tack coat shall be evenly applied at a rate of between 0.4 L/m^2 and 0.6 L/m^2 using a spray machine complying with BS 434: Part 2 Bituminous materials shall not be laid until the tack coat has cured. Constructional Plant and other vehicles necessary shall only run on the tack coat as necessary to lay the bituminous materials.

(5) If approved by the Engineer, surfaces of existing carriageways may be regulated before the overlying bituminous material is laid; bituminous regulating course material shall be a material approved by the Engineer complying with the requirements for the 10 mm nominal maximum aggregate size wearing course material as specified in Table 9.3. Regulating course material shall be laid by paving machines unless laying by manual methods is instructed by the Engineer.

(6) Bituminous materials shall comply with the temperature requirements as stated in Table 9.7 during laying and compaction.

Laying bituminous materials by paving machine

9.31 (1) Unless otherwise permitted by the Engineer, bituminous materials shall be placed and spread using a self-propelled paving machine with a screw auger and attached screed capable of spreading and laying the material to the full width required. The paving machine shall be capable of giving initial compaction to the material and finishing it to a level suitable for subsequent compaction.

(2) Paving machines may be fitted with cut-off shoes or extensions to limit or extend the width of the screed; screed extensions shall not be used unless the screw auger is extended in accordance with the manufacturer's recommendations. The surface texture produced by paving machines shall be free from segregation and from pushing or dragging marks.

(3) Bituminous materials laid by paving machines shall be placed directly from the vehicles transporting the material into the hopper of the paving machine. Delivery of materials to the paving machine and laying of the materials shall be at a uniform rate appropriate to the capacity of the paving machine and compaction plant.

(4) If any delay in laying operations occurs, the paving machine shall be removed, the uncompacted cold material shall be removed and a transverse joint shall be formed as stated in Clause 9.34.

(5) Paving machines working in echelon shall be as close as practicable; the machines shall be not more than 30 m apart unless a longitudinal joint is formed as stated in Clause 9.34.

(6) Manual placing of materials on freshly laid surfaces shall only be used for the purpose of locally correcting levels as paving operations proceed, before compaction by rolling is commenced.

Laying bituminous materials by manual methods

9.32 Bituminous materials shall be laid by manual methods only if in the opinion of the Engineer the use of a paving machine is impracticable. If approved by the Engineer, bituminous materials may be laid by manual methods:

(a) in courses of irregular shape and varying thickness,

(b) in confined locations,

(c) adjacent to expansion joints, covers, frames and other hardware, and

(d) in reinstatements to trenches.

Compaction of bituminous materials and sub-base material

9.33 (1) The minimum compaction plant to be used to compact bituminous roadbase, base course, regulating course, wearing course and sub-base material shall be:

(a) a smooth three-wheeled steel-wheeled roller with a mass of between 6 t and 12 t, or a vibratory tandem steel-wheeled roller with an effective mass of between 6 t and 12 t, and a smooth pneumatic tyred-roller with a mass of between 12 t and 25 t, and with not less than seven overlapping wheels which have tyres that are capable of having pressures varying between 300 MPa and 800 MPa, and suitable mechanical rammers and hand-tools, or

(b) other types of rollers, vibrating plates and rammers approved by the Engineer, or other similar plant approved by the Engineer, necessary to produce the required degree of compaction.

(2) Bituminous roadbase, base course, regulating course and wearing course materials shall be initially rolled using a steel-wheeled roller operated in a longitudinal direction along the carriageway with the driving wheels nearest the paving machine.

(3) All roller marks shall be removed from the surface of bituminous roadbase, base course and wearing course materials using either a smooth-wheeled dead-weight roller or a smooth-wheeled vibratory roller in non-vibrating mode.

(4) Bituminous friction course material shall be compacted using rollers as stated in Clause 9.33(1)(a) without the application of vibration; rollers shall not have an excessive film of water over the front and rear wheels. Bituminous friction course material shall be compacted until all roller marks are removed and compaction is complete.

(5) Rollers shall not be parked on newly laid or compacted bituminous materials.

(6) Bituminous materials immediately adjacent to kerbs, covers, frames and other hardware where rollers cannot operate effectively shall be compacted using hand-operated mechanical compaction plant.

Joints in bituminous materials

9.34 (1) The screed of the paving machine shall overlap previously laid strips of bituminous material by at least 50 mm and shall be sufficiently high that compaction will produce a smooth dense flush joint. Bituminous materials overlapping the previously laid strip shall be pushed back to the edge of the previously laid strip and the excess material shall be removed.

(2) Longitudinal joints in friction course or wearing course shall be formed coincident with the specified position of the lane-markings unless otherwise permitted by the Engineer.

(3) A prepared joint shall be formed between hot bituminous material and cold material or existing bituminous material which is at a temperature below the minimum specified laying temperature.

(4) The distance between prepared longitudinal joints in different layers shall be at least 150 mm and the distance between prepared transverse joints in different layers shall be at least 500 mm.

(5) Prepared joints in base course and wearing course shall be formed by cutting back the face of the cold material or existing bituminous material for a minimum distance of twice the depth of the layer or 100 mm, whichever is greater; a vertical face shall be cut for the full depth of the layer. All loosened materials shall be removed and the face shall be coated with bituminous emulsion; the bituminous emulsion shall not be applied beyond the edges of the joint. The hot bituminous materials shall be laid and compacted against the coated face with a joint formed as stated in this clause.

(6) Unless otherwise permitted by the Engineer friction course joints shall not be coated with bituminous emulsion.

PROTECTION OF SURFACES OF SUB-BASE MATERIAL AND BITUMINOUS MATERIALS

Protection of surfaces of sub-base material and bituminous materials

9.35 (1) The surface of each layer of sub-base material and bituminous materials shall be kept clean and free from deleterious material. If instructed by the Engineer, bituminous priming coat shall be applied to the final surface of the sub-base layer at a rate of between 0.9 L/m^2 and 1.1 L/m^2.

(2) Layers of carriageways under construction shall not be used by Constructional Plant or vehicles other than those which in the opinion of the Engineer are essential to construct the work.

(3) Unless otherwise permitted by the Engineer, bituminous courses shall not be used by Constructional Plant or other vehicles until 6 hours after the material has been laid and compacted.

TOLERANCES

Tolerances: alignment of carriageway

9.36 The line of the edges of carriageways shall be within 25 mm of the specified line, except at the edges of structures where it shall be within 6 mm.

Tolerances: level of carriageway

9.37 (1) The levels of the surface of each layer of sub-base, roadbase, base course, wearing course and friction course shall be determined on a grid at 10 m centres in the longitudinal direction and at 2 m centres in the transverse direction.

(2) The level of the surface of each layer of sub-base, roadbase, base course, wearing course and friction course shall be within the tolerances stated in Table 9.8.

(3) The difference in level of the surface of wearing course and friction course across joints shall not exceed 3 mm.

(4) The combination of permitted tolerances in levels shall not result in a reduction in the thickness of the pavement, excluding the sub-base, of more than 15 mm from the specified thickness nor a reduction in the thickness of the bituminous wearing course or friction course of more than 5 mm from the specified thickness.

Table 9.8: Tolerances in level

Type of surface	Permitted tolerance in level (mm)
Sub-base	+ 10 - 20
Roadbase course	+ 8 - 15
Base course	± 6
Wearing course	
Friction course	

Tolerances: covers, frames and other hardware

9.38 The level of covers, frames and other hardware shall be not lower than, and shall not be more than 5 mm higher than the surface of the carriageway. The level of gully gratings shall not be higher than, and shall not be more than 5 mm lower than, the surface of the carriageway.

TESTING: SURFACE REGULARITY

Testing: surface regularity

9.39 The surface regularity of the final layer of the pavement shall be determined as stated in Clause 10.55.

Compliance criteria: surface regularity

9.40 The results of tests for surface regularity shall comply with Clause 10.56.

TESTING: SUB-BASE MATERIAL

Batch: sub-base material 9.41 A batch of sub-base material is a quantity not exceeding 250 m^3 of sub-base material of the same type and same mix produced at the same mixing plant, and delivered to the Site at any one time.

Samples: sub-base material 9.42 (1) Unless otherwise permitted by the Engineer, one sample of each type of sub-base material shall be provided from each batch of sub-base material delivered to the Site.

(2) The size of each sample shall be at least 50 kg. The method of sampling shall be in accordance with BS 812: Part 102.

Testing: sub-base material 9.43 (1) Each sample of sub-base material shall be tested to determine the particle size distribution, ten percent fines value, maximum dry density, optimum moisture content and plasticity index of the portion passing a 425μm BS test sieve.

(2) The method of testing for particle size distribution shall be in accordance with BS 812: Part 103.1.

(3) The method of testing for ten percent fines value shall be in accordance with BS 812: Part 111, except that the sample shall be soaked in water at room temperature for 24 hours and shall not be oven-dried before testing.

(4) The method of testing for plasticity index shall be in accordance with Geospec 3, Test Method 6.1, except that sample preparation shall be by wet sieving the material over a 425 μm BS test sieve.

(5) The method for testing for maximum dry density and optimum moisture content shall be in accordance with Geospec 3, Test Method 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7 or 10.8, and Appendix 6.5 of this Specification, whichever as instructed by the Engineer. **COR No. 3/2003(Dec)**

TESTING: RELATIVE COMPACTION OF SUB-BASE

Testing: relative compaction of sub-base 9.44 (1) Each area of sub-base which contains sub-base material of the same type and same mix produced at the same mixing plant and which is laid and compacted in a single layer in one day shall be tested to determine the relative compaction. Tests shall be carried out after the sub-base material has been laid and compacted in the final position.

(2) Two tests shall be carried out on each area of 1000 m^2 or part thereof laid and compacted each day.

(3) Tests shall be carried out at positions which in the opinion of the Engineer are representative of the area of compacted sub-base as a whole.

(4) The method of testing for relative compaction shall be as stated in Clause 6.68(4). **COR No. 3/2003(Dec)**

Compliance criteria: relative compaction of sub-base

9.45 The results of tests for relative compaction of sub-base shall comply with the requirements stated in Clause 9.29(6).

Non-compliance: relative compaction of sub-base

9.46 If the result of any test for relative compaction of sub-base does not comply with the specified requirements for relative compaction of sub-base, the area shall be recompacted and two additional tests for relative compaction of sub-base shall be carried out on the area.

TESTING: AGGREGATES, FILLER AND BITUMEN FOR BITUMINOUS MATERIALS

Batch: aggregates, filler and bitumen for bituminous materials

9.47 A batch of aggregates, filler or bitumen for bituminous materials is any quantity of aggregates, filler or bitumen for bituminous materials of the same type, manufactured or produced in the same place and covered by the same certificates delivered to the Site at any one time.

Samples: aggregates, filler and bitumen for bituminous materials

9.48 (1) One sample of each type of aggregate, filler and bitumen for bituminous materials shall be provided from each batch.

(2) The size of each sample and the method of sampling shall be as stated in Table 9.9.

Table 9.9: Size of samples and method of sampling for aggregates, filler and bitumen

Material	Minimum size of sample	Method of sampling
Aggregate, nominal maximum aggregate size exceeding 28 mm	50 kg	BS 812: Part 102
Aggregate, nominal maximum aggregate size 5 mm to 28 mm	25 kg	
Aggregate, nominal maximum aggregate size less than 5 mm	10 kg	
Filler	5 kg	ASTM D 242
Bitumen	2 litres	ASTM D 140

Testing: aggregates, filler and bitumen for bituminous materials

9.49 Each sample of aggregate, filler and bitumen for bituminous materials shall be tested to determine the properties stated in Table 9.10. The method of testing shall be as stated in Table 9.10.

Table 9.10: Testing aggregates, filler and bitumen for bituminous materials

Material	Property	Method of testing
Coarse aggregate	Relative density Water absorption	BS 812: Part 2
	Ten percent fines value	BS 812: Part 111
	Particle size distribution	BS 812: Part 103.1
	Flakiness index	BS 812: Part 105
Fine aggregate	Relative density Water absorption	BS 812: Part 2
	Particle size distribution	Geospec 3, Test Method 8.2 **COR No. 3/2003(Dec)**
Filler	Relative density	BS 4550: Part 3
	Particle size distribution	BS 812: Part 103.1
Bitumen	Relative density	ASTM D 3289
	Softening point	BS 2000
	Penetration	ASTM D 5
	Ductility	ASTM D 113
	Retained penetration after thin film oven test	ASTM D 1754
	Solubility	ASTM D 2042
	Viscosity	ASTM D 2171 or BS 2000
	Loss on heating	BS 2000

TESTING: BITUMINOUS MATERIALS OTHER THAN BITUMINOUS FRICTION COURSE MATERIAL

Batch: bituminous materials other than bituminous friction course material

9.50 A batch of bituminous materials other than bituminous friction coarse material is a quantity not exceeding the limits stated in Table 9.11 of bituminous materials of the same type and same mix produced at the same mixing plant in one day.

Table 9.11: Maximum size of batch for bituminous materials other than bituminous friction course material

Material	Maximum batch size
Wearing course	100t
Base course	150t
Road base	200t

Samples: bituminous materials other than bituminous friction course material

9.51 (1) One sample of bituminous materials other than bituminous friction course material shall be provided from each batch unless otherwise required by the Engineer.

(2) The size of each sample shall be as stated in Table 9.12.

(3) Samples shall be taken at the mixing plant or at the location where the bituminous material will be laid as instructed by the Engineer. Samples taken at the mixing plant shall be taken from the delivery vehicle immediately after loading from the plant or from the surge bin. Samples taken at the location where the bituminous materials will be laid shall be taken from the delivery vehicle.

(4) Unless otherwise agreed by the Engineer the method of sampling shall be in accordance with ASTM D 979.

Table 9.12: Size of samples for bituminous materials other than bituminous friction course material

Material	Minimum size of sample (in kg)
Wearing course (10mm nominal maximum aggregate size)	10
Wearing course (20mm nominal maximum aggregate size)	16
Base course	24
Roadbase	24

Testing: bituminous materials other than bituminous friction course material

9.52 (1) Each sample of bituminous materials taken as stated in Clause 9.51(1) shall be tested to determine the particle size distribution, bitumen content and Rice's specific gravity.

(2) The method of testing shall be in accordance with the following:

Particle size distribution	:	ASTM C 136 with modifications and ASTM C 117, Method B
Bitumen content	:	ASTM D 2172, Method A
Rice's specific gravity	:	ASTM D 2041, Weighing-in-water method
Bulk specific gravity	:	ASTM D 2726

(3) For particle size distribution tests in accordance with ASTM C 136, the modifications are:

(a) Sieves to BS 410 instead of sieves to ASTM E 11 shall be used.

(b) Each sample of bituminous materials taken as stated in Clause 9.51 shall be reduced to a test specimen of suitable size as follows:

Nominal Maximum Aggregate Size (mm)	Minimum Sample Size (kg)
37.5	2.5
28.0	2.0
20.0	1.5
10.0	1.0

(4) The residual pressure manometer specified in ASTM D 2041 may be replaced by a vacuum gauge.

Compliance criteria: bituminous materials other than bituminous friction course material

9.53 The results of tests on bituminous materials other than bituminous friction course material shall comply with the following requirements:

(a) The particle size distribution shall be such that not more than two points on the particle size distribution curve are outside the approved gradation envelopes determined as stated in Clause 9.20(2). The percentage passing the 75 μm BS test sieve shall not exceed the approved design value by more than 3%.

(b) The bitumen content shall be within the approved bitumen content range determined as stated in Clause 9.20(3).

TESTING: BITUMINOUS FRICTION COURSE MATERIAL

Batch: bituminous friction course material

9.54 A batch of bituminous friction course material is a quantity not exceeding 100 t of bituminous friction course material of the same mix produced at the same mixing plant in one day.

Samples: bituminous friction course material

9.55 (1) One sample of bituminous friction course material shall be provided from each batch of bituminous friction course material.

(2) The size of each sample shall be at least 15 kg.

(3) Samples shall be taken at the mixing plant from the delivery vehicle immediately after loading from the plant or from the surge bin.

(4) Unless otherwise agreed by the Engineer the method of sampling shall be in accordance with ASTM D 979.

Testing: bituminous friction course material

9.56 (1) Each sample of bituminous friction course material shall be tested to determine the particle size distribution and bitumen content.

(2) The method of testing shall be in accordance with the following:

Particle size distribution	:	ASTM C 136 with modifications and ASTM C 117, Method B
Bitumen content	:	ASTM D 2172, Method A

(3) For particle size distribution tests in accordance with ASTM C 136, the modifications are:

(a) Sieves to BS 410 instead of sieves to ASTM E 11 shall be used.

(b) Each sample of bituminous materials taken as stated in Clause 9.55 shall be reduced to a test specimen of suitable size as follows:

Nominal Maximum Aggregate Size (mm)	Minimum Sample Size (kg)
37.5	2.5
28.0	2.0
20.0	1.5
10.0	1.0

Compliance criteria: bituminous friction course material

9.57 The results of tests on bituminous friction course material shall comply with the following requirements:

(a) The particle size distribution shall be within the approved gradation envelopes as determined in Clause 9.20(2).

(b) The bitumen content shall be within the approved bitumen content range as determined in Clause 9.20(3).

TESTING: BITUMINOUS MATERIAL CORES

Samples: bituminous material cores

9.58 (1) Each area of roadbase, base course and wearing course which contains bituminous material of the same type and same mix produced at the same mixing plant and which is laid and compacted in a single layer in one day shall be tested to determine the compacted layer thickness.

(2) Unless otherwise approved by the Engineer each area of bituminous material to be tested shall be divided into approximately equal sub-areas as stated in Table 9.13. One core shall be taken at random from each sub-area.

(3) Cores shall not be taken from within 300 mm of covers, frames and other hardware, or construction joints in the bituminous material.

(4) Cores shall be taken by a mechanically operated coring machine.

(5) Cores shall be 150 mm diameter for bituminous material with a designed layer thickness of 40 mm or greater and shall be 100 mm diameter for bituminous material with a designed layer thickness of less than 40 mm.

(6) Cores shall be taken as soon as practicable but not later than 48 hours after completion of the paving operation.

(7) If agreed by the Engineer, the sampling rate for roadbase may be applied to wearing course and base course.

(8) Holes formed by taking cores shall be filled with compatible bituminous material as soon as practicable after the core has been taken.

Table 9.13: Rate of sampling for bituminous material cores

Area of bituminous material laid and compacted in one day	No. of sub-areas/cores	
	Roadbase	Wearing course and Base course
< 5 000 m^2	4	10
5 000 - 10 000 m^2	10	15
> 10 000 m^2	20	20

Testing: bituminous material cores

9.59 (1) Each bituminous material core shall be measured to determine the compacted layer thickness of the bituminous material and tested to determine the air void content.

(2) The method of testing for air void content shall be in accordance with ASTM D 3203.

Compliance criteria: bituminous material cores

9.60 The results of tests on bituminous material cores shall comply with the following requirements:

(a) The average air void content of the cores taken from an area of bituminous base course or wearing course material shall be not less than 3.0% and not greater than 6.0%.

(b) The air void content of each core taken from an area of

bituminous base course or wearing course material shall be not less than 2.5% and not greater than 7.5%.

(c) The air void content of each core taken from an area of bituminous roadbase material shall be not less than 3.0% and not greater than 9.0%.

(d) The compacted layer thickness as measured from each core shall comply with the thickness requirements stated in Clause 9.37(4) and shall be compatible with the level tolerances stated in Table 9.8.

Non-compliance: bituminous material cores

9.61 (1) If the result of any test for air void content of cores does not comply with the specified requirements for air void content, the following procedure shall apply:

(a) Four additional cores shall be taken from each sub-area for which the original core did not comply with the specified requirements for air void content. The cores shall be taken at locations evenly spaced throughout the sub-area such that in the opinion of the Engineer they are representative of the sub-area as a whole.

(b) Each additional core shall be tested to determine the air void content and the test results of the additional cores from the same sub-area shall be averaged.

(c) The average air void content of the sub-area thus obtained shall replace the original air void content of the respective sub-area. The new average air void content of the area of bituminous material tested shall then be calculated for compliance checking.

(2) If the air void content of any of the four additional cores determined as stated in Clause 9.59(2) is less than 2.5% or greater than 7.5% for bituminous base course material and bituminous wearing course material, or less than 3.0% or greater than 9.0% for bituminous roadbase material, the sub-area from which the cores were taken shall be considered as not complying with the specified requirements.

(3) The area of bituminous material tested shall be considered as not complying with the specified requirements for average air void content if the average air void content of the cores taken from the area does not comply with the specified requirements for average air void content.

(4) If the result of any test for compacted layer thickness of cores is not compatible with the requirements of Table 9.8 or Clause 9.37(4), four additional cores shall be taken from the same sub-area and the average compacted layer thickness determined. The cores shall be taken at locations evenly spaced throughout the sub-area such that in the opinion of the Engineer they are representative of the sub-area as a whole.

(5) If the average compacted layer thickness determined as stated in Clause 9.61(4) is not in accordance with the permitted compacted layer thickness stated in Clause 9.60(d), the sub-area from which the cores were taken shall be considered as not complying with the specified requirements.

TESTING: TEXTURE DEPTH AND PERMEABILITY

Testing: texture depth and permeability

9.62 (1) Unless otherwise agreed by the Engineer each area of friction course to be tested shall be divided into approximately equal sub-areas as stated in Table 9.14. Tests for texture depth and permeability shall be carried out on each sub-area at positions which in the opinion of the Engineer are representative of the sub-area of friction course as a whole. No measurement shall be taken within 300 mm of the longitudinal edge of the carriageway.

(2) If agreed by the Engineer the number of tests for texture depth and permeability may be reduced to the minimum stated in Table 9.14.

(3) Tests shall be carried out before the area of friction course is used by Constructional Plant or other vehicles.

(4) Testing to determine the texture depth will be carried out by the Engineer. The method of testing shall be by the sand patch test in accordance with Appendix 10.1.

(5) Testing to determine the permeability will be carried out by the Engineer. The method of testing shall be in accordance with Appendix 9.1.

Compliance criteria: texture depth

9.63 The results of tests for texture depth on an area of friction course shall comply with the following requirements:

(a) The average texture depth shall not be less than 1.5 mm.

(b) Not more than one of the tests for texture depth shall give a result of less than 1.2 mm.

Compliance criteria: permeability

9.64 The time for 150 mL of water to drain into the friction course in the permeability test stated in Clause 9.62(5) shall not exceed 30 seconds.

Table 9.14: Rate of testing for texture depth and permeability

Area of bituminous material laid and compacted in one day	No. of sub-areas/tests	
	Normal	Minimum
< 5 000 m^2	10	4
5 000 - 10 000 m^2	15	10
> 10 000 m^2	20	20

APPENDIX 9.1

DETERMINATION OF THE PERMEABILITY OF FRICTION COURSE MATERIAL

Scope 9.1.1 This method covers the determination of the permeability of friction course material by measuring the time taken for 150 mL of water to drain into the material.

Apparatus 9.1.2 The following apparatus is required:

(a) A non-porous ring with an internal diameter of 150 mm ± 2 mm, and a minimum height of 20 mm.

(b) Suitable sealant for sealing one end of the ring onto the friction course surface.

(c) A measuring cylinder for measuring 150 mL of water to an accuracy of 1 mL.

(d) Two containers, each suitable for containing and pouring 150 mL of water.

(e) A stop watch.

Procedure 9.1.3 The procedure shall be as follows:

(a) Carefully inspect the specified test location and record any unusual features.

(b) Place one end of the ring on the friction course at the location to be tested, and seal the interface with sealant to prevent any leakage of water.

(c) Prepare two volumes of water of 150 mL each using the measuring cylinder and the two containers.

(d) Pour one 150 mL measure of water into the ring quickly and steadily without spillage.

(e) As soon as all of the water has drained into the friction course, pour the second 150 mL of water into the ring quickly and steadily without spillage, and at the same time start the stop watch.

(f) Record the time taken for the second 150 mL of water to drain into the friction course surface.

Reporting of results 9.1.4 The following shall be reported:

(a) The test location.

(b) The time taken for the second 150 mL of water to drain into the friction course surface, to the nearest one second.

(c) That the test was carried out in accordance with this Specification.

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 10

CONCRETE CARRIAGEWAYS

SECTION 10

CONCRETE CARRIAGEWAYS

GENERAL

General requirements 10.01 The works and materials specified in Clauses 10.02 to 10.06 shall comply with the sections stated, unless otherwise stated in this Section.

Formwork and finishes 10.02 Formwork and finishes to concrete for concrete carriageways shall comply with Section 14.

Reinforcement 10.03 Steel reinforcement for concrete carriageways shall comply with Section 15.

Concrete 10.04 Concrete for concrete carriageways shall comply with Section 16.

Curing compound 10.05 Curing compound for concrete carriageways shall comply with Section 16.

Earthworks 10.06 Earthworks for concrete carriageways shall comply with Section 6.

MATERIALS

Reinforcement 10.07 (1) Fabric reinforcement shall be steel fabric complying with BS 4483; the fabric shall be manufactured from steel wire which complies with BS 4482 and which has a type 2 bond classification.

(2) Dowel bars, tie bars, cradles and tie bars for cradles shall be Grade 250 plain round steel bars complying with CS 2. Dowel bars and tie bars shall be straight; both ends of dowel bars and one end of tie bars shall be sawn square with all burrs removed.

Cement mortar for cradles 10.08 Cement mortar for supporting cradles shall consist of 1 part of cement to 3 parts of fine aggregate together with the minimum amount of water necessary to achieve a consistency suitable for the required work. Fine aggregates shall be sand or crushed rock to BS 1200 and shall pass a 5 mm BS test sieve.

Fine aggregate 10.09 Fine aggregate for concrete shall be natural river-deposited sand consisting of at least 95% by mass of quartz grains.

Polyethylene sheeting 10.10 Polyethylene sheeting shall be impermeable and shall have a nominal thickness of 0.125 mm.

Joint filler 10.11 Joint filler shall be a proprietary type approved by the Engineer and shall be a firm, compressible, single thickness, non-rotting filler.

Joint sealant 10.12 (1) Joint sealant shall be of a grade suited to the climatic conditions of Hong Kong and shall perform effectively over a temperature range of 0°C to 60ºC.

(2) Joint sealant shall be a cold poured two-part polymer-based sealant complying with BS 5212, Type N.

(3) Primers and caulking material for use with joint sealant shall be proprietary types recommended by the joint sealant manufacturer and approved by the Engineer.

Bond breaker tape 10.13 Bond breaker tape shall be a proprietary type recommended by the joint sealant manufacturer and approved by the Engineer. The tape shall be a polyethylene film with adhesive applied on one side and shall be the full width of the groove.

Groove forming strip 10.14 (1) Groove forming strip shall be a proprietary type approved by the Engineer. The strip shall be a firm compressible strip of either ethylene vinyl acetate foam with a density of at least 90 kg/m^3 or synthetic rubber. The strip shall be 25 mm deep and 5 mm thick and shall be sufficiently rigid to remain in position during concreting without deforming or stretching.

(2) Adhesive for groove forming strip shall be a proprietary type recommended by the groove forming strip manufacturer and approved by the Engineer.

Sleeves for dowel bars and tie bars 10.15 Sleeves for dowel bars and tie bars shall be PVC and shall have a nominal wall thickness not exceeding 1.5 mm; the sleeves shall fit tightly to the bars.

Epoxy resin grout 10.16 Epoxy resin grout shall be a proprietary type approved by the Engineer.

CONCRETE

Concrete mix 10.17 Concrete for concrete carriageways shall comply with the following requirements:

(a) Concrete shall be Grade 40/20 and shall be a designed mix.

(b) The concrete mix shall contain either PPFAC or a minimum of 265 kg of OPC plus a minimum of 85 kg of PFA per m^3 of compacted concrete.

(c) The percentage by mass of fine aggregate to total aggregate shall be at least 30%.

(d) The workability in terms of designed slump value shall not exceed 30 mm.

Cementitious content of concrete 10.18 The minimum cementitious content of concrete for concrete carriageways shall be 350 kg/m^3.

SUBMISSIONS

Particulars of materials for joints

10.19 (1) The following particulars of the proposed materials for joints in concrete carriageways shall be submitted to the Engineer:

(a) manufacturer's literature and a certificate for joint filler showing the manufacturer's name, the date and place of manufacture and showing that the joint filler complies with the requirements stated in the Contract and including results of tests for:

- disintegration and shrinkage
- recovery value and reduction in mass
- extrusion,

(b) manufacturer's literature for joint sealant, including details of the method and time required for mixing the different components, and a certificate showing the manufacturer's name, the date and place of manufacture and showing that the sealant complies with the requirements stated in the Contract and including results of tests for:

- application life
- tack-free time
- resistance to flow
- recovery
- adhesion and cohesion in tension and compression
- resistance to heat ageing,

(c) manufacturer's literature and a certificate for groove forming strip showing the manufacturer's name, the date and place of manufacture and showing that the groove forming strip complies with the requirements stated in the Contract and including results of tests for density, and

(d) particulars of primers and caulking material for joint sealant, adhesive for groove forming strip, bond breaker tape and sleeves for dowel bars and tie bars.

(2) The particulars, including certificates, shall be submitted to the Engineer at least 14 days before the first delivery of the material to the Site. Certificates shall be submitted for each batch of the material delivered to the Site.

Particulars of methods of construction

10.20 Particulars of proposed methods of construction for concrete carriageways shall be submitted to the Engineer at least 7 days before the trial length is constructed.

Samples of materials 10.21 Samples of the following proposed materials shall be submitted to the Engineer at the same time as particulars of the material are submitted:

(a) polyethylene sheeting,

(b) joint filler,

(c) bond breaker tape,

(d) groove forming strip, and

(e) sleeves for dowel bars, including compressible filler, and for tie bars.

TRIALS

Compliance criteria: trial mix concrete 10.22 The results of the tests on trial mix concrete for concrete carriageways shall comply with the following requirements:

- Each of the six slump values shall not exceed 40 mm, and the average of the six slump values shall not exceed 35 mm.

Trial length 10.23 (1) A trial length of concrete carriageway shall be constructed to demonstrate that the proposed materials, mix design, methods of production and methods of construction will produce a concrete carriageway which complies with the specified requirements.

(2) The trial length shall be constructed using the materials, mix design, methods of production and methods of construction submitted to the Engineer.

(3) If it is not stated in the Contract that the trial length is to be constructed in a location separate from the permanent carriageway, the trial length shall be the first 30 m of the permanent carriageway, or such other length agreed by the Engineer. The trial length shall be constructed over a width of two bays and shall include at least one expansion joint, one contraction joint and the longitudinal joint between the bays.

(4) The Contractor shall inform the Engineer at least 48 hours, or such shorter period agreed by the Engineer, before constructing the trial length.

(5) The trial length shall be completed in sufficient time before the permanent carriageway is constructed to allow the Engineer a period of at least 7 days to determine if the specified requirements have been complied with in the trial length.

(6) The trial length shall be protected from damage and shall be left in position unless the Engineer instructs its removal. A trial length which forms part of the permanent carriageway and which complies with the specified requirements shall not be removed.

Testing: trial length

10.24 (1) The trial length shall be tested to determine the accuracy of the alignment and level, the surface regularity and the texture depth. The method of testing the surface regularity shall be as stated in Clause 10.55. The method of testing the texture depth shall be as stated in Clause 10.57.

(2) Concrete cores shall be cut from the trial length to determine the thickness of the slab, the positions of the reinforcement and joint components, the amount of segregation of the constituents and the presence of voids. The method of taking, preparing, inspecting and testing concrete cores shall be as stated in Clauses 10.62 and 10.63.

Compliance criteria: trial length

10.25 The results of tests on trial lengths shall comply with the following requirements:

(a) The alignment, levels and thickness of the carriageway shall comply with Clauses 10.53 and 10.54.

(b) The surface regularity shall comply with Clause 10.56.

(c) The texture depth shall comply with Clause 10.58.

(d) The positions of the reinforcement and joint components shall comply with Clauses 10.49, 10.50, 10.51 and 10.53.

(e) The amount of segregation of the constituents and the presence of voids shall comply with Clause 10.64.

Non-compliance: trial length

10.26 (1) If the result of any test on the trial length does not comply with the specified requirements for the trial length, particulars of proposed changes to the materials, mix design, methods of production or methods of construction shall be submitted to the Engineer; further trial lengths shall be constructed until the result of every test on the trial length complies with the specified requirements for the trial length. Further trial mixes shall be made unless in the opinion of the Engineer non-compliance of the trial length was not due to the concrete mix.

(2) Unless otherwise permitted by the Engineer, trial lengths, or parts of trial lengths, which do not comply with the specified requirements for the trial length shall be removed.

Commencement of concreting

10.27 (1) Concrete shall not be placed in the permanent carriageway other than in a trial length until the result of every test on the trial length complies with the specified requirements for the trial length.

(2) Concrete may be placed in the permanent carriageway before the results of tests for compressive strength of the trial mix are available provided that the result of every other test on the trial mix and trial length complies with the specified requirements for trial mix concrete and for the trial length.

Changes in materials and methods of construction

10.28 Unless permitted by the Engineer, the materials, mix design, methods of production and methods of construction used to produce a trial length which complies with the specified requirements shall not be changed.

STORAGE OF MATERIALS

Storage of materials for joints and polyethylene sheeting 10.29 (1) Joint sealant, primer for joint sealant and adhesive for groove forming strip shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may adversely affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.

(2) Polyethylene sheeting, joint filler, bond breaker tape, groove forming strip and sleeves for dowel bars and tie bars shall be stored in accordance with the manufacturers' recommendations in a dry, weatherproof store with a raised floor. Joint filler shall be stored in sealed plastic bags and shall not be exposed to moisture or air.

PRELIMINARY WORK

Installation of utilities 10.30 (1) Pipes, cables, manholes, chambers, gullies and other utilities below concrete carriageways shall be completed and fill material shall be deposited and compacted in trenches before the carriageway is constructed. Openings to manholes, chambers and gullies shall be protected by temporary covers or by other methods agreed by the Engineer.

(2) Box-outs shall be formed in concrete carriageways for covers, frames and other hardware; the covers, frames and other hardware shall be fixed in position after the main slab has been concreted and before the infill slab is concreted.

Preparation of formation and sub-base 10.31 Construction of concrete carriageways shall start as soon as practicable after the formation or sub-base has been completed. The formation shall be protected as stated in Clause 6.52 and the sub-base shall be protected as stated in Clause 9.35 until construction of the carriageway starts.

Laying polyethylene sheeting 10.32 Polyethylene sheeting below concrete carriageways shall be laid flat without creases. Laps shall be at least 300 mm and there shall be no gaps at the edges of bays.

FORMWORK

Formwork 10.33 (1) Unless otherwise approved by the Engineer, formwork for concrete carriageways shall be steel. The finish to concrete surfaces for transverse and longitudinal joints shall be Class F3; the finish to concrete surfaces for other edges of the carriageway shall be Class F2.

(2) Concrete shall not be placed against excavated surfaces or against kerbs unless permitted by the Engineer.

(3) Formwork shall not be loosened or removed until at least 7 hours after concreting has been completed.

FORMING JOINTS

Forming joints 10.34 (1) Materials for joints in concrete carriageways shall be used in accordance with the manufacturers' recommendations or as otherwise stated in the Contract.

(2) Dowel bars, tie bars and their sleeves shall be securely fixed in position through holes in the formwork before concreting. The bars shall be parallel to the top surface of the slab and to each other. Bars at transverse joints shall be parallel to the adjacent longitudinal joint or to the longitudinal axis of the carriageway if there is no longitudinal joint or to other lines instructed by the Engineer.

(3) Joint filler shall be cut to size before fixing and shall be securely fixed in position to the existing concrete surface before concreting. There shall be no gaps between the joint filler and the formation. Holes in joint filler for dowel bars shall be cut to form a sliding fit to the sleeved bar.

(4) Joints shall be formed perpendicular to the top surface of the slab.

Transverse joints 10.35 (1) Unless otherwise permitted by the Engineer, transverse joints in concrete carriageways shall be straight and perpendicular to the longitudinal axis of the carriageway.

(2) Transverse expansion joints and transverse contraction joints shall be formed only at the specified positions. The joints shall be continued across longitudinal joints and shall be in line and of the same type on both sides of the longitudinal joint. The joints shall be continued through kerbs, edgings and quadrants and their foundation and backing; the joint dimensions and materials shall be the same as the transverse joints with the omission of dowel bars. The location of additional contraction joints in accordance with Clause 11.54(3) shall be as instructed by the Engineer.

(3) The joint filler and groove for joint sealant at transverse expansion joints shall provide complete separation of adjacent slabs.

Longitudinal joints 10.36 Longitudinal joints in concrete carriageways shall be formed only at the specified positions.

Isolation joints 10.37 Isolation joints shall be formed in concrete carriageways at manholes and chambers.

Forming grooves 10.38 (1) Grooves in concrete carriageways for joint sealant shall be straight, shall have parallel sides and shall be perpendicular to the top surface of the slab. The bottom of the groove shall be flat and shall be parallel to the top surface of the slab.

(2) Grooves at transverse expansion joints and at isolation joints at manholes and chambers shall be formed by sawing the groove to the specified width and depth not less than 7 days after concreting. The grooves shall be located over the joint filler such that the upper surface of the joint filler is entirely contained in the groove.

(3) Grooves at transverse contraction joints shall be formed using one of the following methods:

Method 1: An initial groove shall be sawn as soon as practicable after concreting without causing spalling of the edges. The width of the initial groove shall be less than the specified width of the final groove and the depth of the initial groove shall be between 1/4 and 1/3 of the thickness of the slab. The final groove shall be sawn to the specified width and depth not less than 7 days after concreting. The centre lines of the initial and final grooves shall coincide.

Method 2: The final groove shall be sawn to the specified width and depth as soon as practicable after concreting without causing spalling of the edges.

(4) Grooves at transverse construction joints shall be formed by fixing groove forming strip with adhesive to the concrete already placed before concreting the adjacent slab.

Protection of grooves 10.39 Before permanent sealing, grooves in concrete carriageways for joint sealant shall be protected from contamination by a temporary sealing strip or by other methods agreed by the Engineer.

Sealing joints 10.40 (1) The permanent sealing of joints in concrete carriageways shall be carried out at least 7 days after concreting unless otherwise permitted by the Engineer.

(2) Immediately before permanent sealing, groove forming strips, temporary seals, dirt and loose material shall be removed from the groove and the sides of the groove shall be cleaned and roughened by water jetting, sand blasting or by other methods agreed by the Engineer.

(3) Caulking material shall be firmly packed in the bottom of the groove if the joint sealant is not required to extend to the bottom of the groove.

(4) Bond breaker tape shall be fixed continuously and evenly along the bottom of the groove for the full width and length of the groove.

(5) Primer for the joint sealant shall be applied to the sides of the groove in accordance with the manufacturer's recommendations.

(6) Joint sealant shall be applied between the minimum and maximum drying times of the primer recommended by the manufacturer. The components of the sealant shall be thoroughly mixed in accordance with the manufacturer's recommendations using a power operated paddle mixer for sufficient time to produce a homogeneous mass without entrapped air. The sealant shall be dispensed into the groove as soon as practicable after mixing and within the time recommended by the manufacturer.

(7) The groove shall be clean and dry at the time of applying the primer and joint sealant.

(8) Excess joint sealant shall be removed by using a purpose made finishing tool such that the finished surface of the sealant is between 4 mm and 6 mm below the surface of the slab.

PLACING AND COMPACTING CONCRETE

Placing and compacting concrete

10.41 (1) Concrete shall be placed continuously between the joints in concrete carriageways unless otherwise permitted by the Engineer.

(2) Concrete in unreinforced slabs shall be placed and compacted to the full thickness of the slab in one operation.

(3) Unless otherwise permitted by the Engineer, concrete in reinforced slabs shall be placed and compacted to the specified level of the fabric reinforcement; the fabric reinforcement shall be placed in position and concrete shall be placed and compacted to the remaining thickness of the slab. The time between compaction of the first layer and placing of the remaining layer shall not exceed 30 minutes unless in the opinion of the Engineer the concrete already placed is sufficiently workable and the permission of the Engineer has been obtained. If permission is not obtained, a construction joint shall be formed as stated in Clause 16.45; concrete shall not be placed against the concrete already placed for at least 24 hours unless permitted by the Engineer.

(4) Concrete in infill slabs at covers, frames and other hardware shall be placed and compacted after the covers, frames and hardware have been fixed in position and shall not be placed at the same time as the concrete in the main slab.

CONSTRUCTION JOINTS

Construction joints

10.42 (1) Construction joints shall be formed in concrete carriageways only where approved by the Engineer or in cases of emergency if concreting is interrupted by adverse weather, plant breakdown or similar circumstances. Construction joints shall not be formed within 2.5 m of an existing or planned expansion or contraction joint.

(2) Transverse construction joints shall be formed by either:

(a) using formwork and cast-in tie bars, or

(b) breaking back from an unformed edge and fixing the tie bars and sleeves with epoxy resin grout in drilled holes.

SURFACE FINISH

Surface regulation

10.43 (1) Unless combined double beam compactor-levellers are being used, then after compaction, the concrete in concrete carriageways shall be struck off to slightly above the levels of the formwork and the surface shall be regulated by a regulating machine or a vibrating beam.

(2) Regulating machines shall be purpose made and shall span the full width of the slab either transversely or obliquely. The machine shall be equipped with at least two oscillating-type transverse screeds and shall be supported on a carriage.

(3) Vibrating beams shall have a steel or aluminium surface and shall be mounted on a separate carriage. The beam shall be driven by a motor to provide a vibration frequency of at least 3500 cycles per minute.

(4) After regulation by the regulating machine or vibrating beam, the surface of the carriageway shall be regulated by at least two passes of a scraping straight-edge with a blade length of at least 1.8 m. Scraping straight-edges which operate in conjunction with regulating machines shall pass across the surface at right angles to the longitudinal axis of the carriageway. If the surface is torn by the straight-edge, the surface shall be regulated again by the regulating machine or vibrating beam and by the scraping straight-edge.

(5) Wooden floats may be used to tamp and regulate small areas of the carriageway as agreed by the Engineer; steel floats or trowels shall not be used.

Surface texturing 10.44 (1) After the surface of the concrete carriageway has been regulated and before the curing compound is applied, the surface, other than the surface of channels and edges of slabs which do not require to be textured, shall be textured by brushing with a wire broom.

(2) The wire broom shall be at least 450 mm wide and shall have two rows of tufts. The rows shall be 20 mm apart and the tufts in each row shall be at 10 mm centres and in line with the centre of the gaps between the tufts in the other row. The tufts shall contain an average of 14 wires, each of 32 gauge and initially 100 mm long. The broom shall be replaced if any tuft wears down to a length of 90 mm.

(3) The surface texture shall be produced by brushing evenly across the slab in one direction at right angles to the longitudinal axis of the carriageway. Brushing shall be carried out after the moisture film has disappeared from the concrete surface and before the initial set is complete.

CURING CONCRETE

Curing concrete 10.45 The surface and edges of concrete carriageways shall be protected by one of the methods stated in Clause 16.46 except that covering with hessian, sacking, canvas or other absorbent material as stated in Method 2 shall not be used. If Method 1 is used, the curing compound shall be applied to the surface immediately after the surface has been textured and shall be applied to the edges immediately after the formwork has been removed.

PROTECTION OF CONCRETE CARRIAGEWAY

Protection of concrete carriageway 10.46 (1) Immediately after the curing system has been applied, the concrete carriageway shall be fenced off from pedestrian traffic and covered with protective sheeting for at least 24 hours. The sheeting shall be lapped and securely held in position in such a manner that the surface of the carriageway will not be damaged.

(2) Loads from materials not forming part of the permanent work or from Constructional Plant or other vehicles shall not be applied to the concrete carriageway until at least 7 days after concreting has been

completed and until all grooves at joints have been temporarily or permanently sealed or protected.

TOLERANCES

Tolerances: sub-base 10.47 The level of the sub-base below concrete carriageways shall not be more than 10 mm higher, and shall not be more than 20 mm lower, than the specified level.

Tolerances: formwork 10.48 (1) The line of formwork for concrete carriageways shall be within 10 mm of the specified line of the concrete carriageway.

(2) The level of the top of the formwork shall be within 3 mm of the specified level of the concrete carriageway.

(3) Abrupt irregularities in the line of the formwork and in the level of the top of formwork shall not exceed 3 mm.

Tolerances: reinforcement 10.49 The cover to fabric reinforcement in concrete carriageways shall be within 10 mm of the specified cover.

Tolerances: dowel bars and tie bars 10.50 (1) Dowel bars at joints in concrete carriageways shall be within 20 mm of the mid-depth of the slab.

(2) Dowel bars shall be parallel to within 3 mm in half the length of the bar to:

(a) the longitudinal joint, or the longitudinal axis of the concrete carriageway if there is no longitudinal joint,

(b) the top surface of the slab, and

(c) adjacent dowel bars.

Tolerances: grooves 10.51 Unless otherwise recommended by the manufacturer of the joint sealant the depth of grooves for joint sealant in concrete carriageways shall be within 3 mm of the specified depth.

Tolerances: covers, frames and other hardware 10.52 The level of covers, frames and other hardware shall not be higher than, and shall not be more than 3 mm lower than, the surface of the adjacent carriageway.

Tolerances: alignment of concrete carriageway 10.53 (1) The best fit straight line of straight joints and of straight edges of concrete carriageways shall be within 25 mm of the specified line. The line of straight joints and of straight edges of concrete carriageways shall be within 10 mm of the best fit straight line.

(2) The best fit curved line of curved joints and of curved edges of concrete carriageways shall be as agreed by the Engineer and shall be within 25 mm of the specified line. The line of curved joints and of curved edges of concrete carriageways shall be within 10 mm of the best fit curved line.

(3) Joints in concrete carriageways shall be continuous across intersections of joints to within 5 mm of the best fit straight lines or best fit curved lines of each joint.

Tolerances: level of concrete carriageway

10.54 (1) The levels of the surface of concrete carriageways shall be determined 200 mm from the edges of each bay at 10 m centres in the longitudinal direction and at 2 m centres in the transverse direction.

(2) The level of the surface of concrete carriageways shall be within 6 mm of the specified level. In low lying and flat areas the Contractor shall pay special attention to level control to ensure that falls on the surface of the carriageway are in the specified direction.

(3) The difference in level of the surface of concrete carriageways across joints shall not exceed 3 mm.

(4) The thickness of concrete carriageway slabs shall not be less than the specified thickness minus 10 mm.

TESTING: SURFACE REGULARITY

Testing: surface regularity

10.55 (1) The surface regularity of concrete carriageways shall be determined by measuring the number of irregularities in the surface. An irregularity means that the gap between the surface of the carriageway, and a 3 m straight-edge placed on the surface of the carriageway, exceeds the specified amount. Irregularities shall be measured in millimetres perpendicular to the straight-edge.

(2) The longitudinal surface regularity of carriageways with a total length of 75 m or more may be measured using a rolling straight-edge of the type designed by the UK Transport and Road Research Laboratory. The longitudinal surface regularity of carriageways with a total length of less than 75 m and the transverse surface regularity of carriageways shall be measured using a 3 m straight-edge.

(3) The longitudinal surface regularity shall be measured along lines parallel to the longitudinal axis of the carriageway and approximately 1 m from the nearside edge of each carriageway lane. The transverse surface regularity shall be measured along lines at right angles to the longitudinal axis of the carriageway at 10 m intervals along the length of the carriageway.

(4) Testing to determine the surface regularity will be carried out by the Engineer.

Compliance criteria: surface regularity

10.56 The results of tests for surface regularity of carriageways shall comply with the following requirements:

(a) The size and number of irregularities in the longitudinal direction shall not exceed the size and permitted number of irregularities stated in Table 10.1.

(b) There shall be no irregularity exceeding 4 mm in a 3 m length in the transverse direction for Category A roads and there shall be no irregularity exceeding 7 mm in a 3 m length in the transverse direction for Category B roads.

Table 10.1: Permitted irregularities in the longitudinal direction

Total length of carriageway	Size of irregularity	Permitted number of irregularities (Category A road)	Permitted number of irregularities (Category B road)
< 75 m	> 4 mm	(9 x total length)/75	(18 x total length)/75
	> 7 mm	1	2
75 m - 300 m	> 4 mm	9 in any 75 m length	18 in any 75 m length
	> 7 mm	1 in any 75 m length	2 in any 75 m length
> 300 m	> 4 mm	20 in any 300 m length	40 in any 300 m length
		9 in any 75 m length	18 in any 75 m length
	> 7 mm	2 in any 300 m length	4 in any 300 m length
		1 in any 75 m length	2 in any 75 m length

Category A roads are roads with a legal speed limit greater than 70 kilometre per hour; all other roads are Category B roads.

Irregularities greater than 7 mm shall also be counted as greater than 4 mm.

No irregularity greater than 10 mm shall be permitted.

TESTING: TEXTURE DEPTH

Testing: texture depth 10.57 (1) The texture depth of concrete carriageways shall be determined by the sand patch test. Tests shall be carried out at least 2 days after the surface texturing has been carried out and before the area is used by Constructional Plant or other vehicles.

(2) Each carriageway lane shall be divided into sections of equal length not exceeding 150 m. Tests shall be carried out at ten locations on each Section at approximately equal spacings as instructed by the Engineer. No measurement shall be taken within 300 mm of the longitudinal edges of the sections.

(3) Testing to determine the texture depth will be carried out by the Engineer. The method of testing shall be in accordance with Appendix 10.1.

Compliance criteria: texture depth 10.58 The results of tests for texture depth for each Section of concrete carriageway lane shall comply with the following requirements:

(a) The average texture depth shall not be less than 0.70 mm, and

(b) Not more than one out of the ten measured texture depths shall be less than 0.6 mm.

TESTING: CONCRETE

Testing: workability and compressive strength of concrete 10.59 Testing to determine the workability and compressive strength of concrete in concrete carriageways shall be as stated in Clauses 16.52 to 16.62 except as stated in Clauses 10.60 and 10.61.

Compliance criteria: workability of concrete 10.60 The average slump value of the two specimens taken from one sample of concrete shall not exceed the approved slump value by more than 10 mm.

Samples: compressive strength of concrete 10.61 One sample of concrete shall be provided from each 25 m^3 or 25 batches of concrete or from the amount of concrete produced each day, whichever is less.

TESTING: CONCRETE CORES FROM TRIAL LENGTHS

Samples: concrete cores from trial lengths 10.62 (1) Two concrete cores shall be provided from each bay, and one core shall be provided from each joint, of concrete carriageway in the trial length. The positions from which the cores are taken shall be as instructed by the Engineer.

(2) Concrete cores shall be 150 mm diameter unless otherwise permitted by the Engineer and shall be the full depth of the slab. Cores shall be taken as soon as the concrete has hardened sufficiently for the core to be taken.

(3) The method of taking concrete cores shall be in accordance with CS1.

(4) Holes formed by taking concrete cores from trial lengths which form part of the permanent carriageway shall be reinstated using the approved concrete mix; joints shall be repaired as instructed by the Engineer.

Testing: concrete cores from trial lengths 10.63 (1) Each concrete core from trial lengths in concrete carriageways shall be inspected to determine the thickness of the slab and the positions of the reinforcement and joint components. Each core shall be inspected for evidence of segregation of the constituents and for the presence of voids.

(2) The method of preparing and inspecting concrete cores shall be in accordance with CS1.

Compliance criteria: concrete cores from trial lengths 10.64 The concrete core shall be considered as non-compliant if it exhibits honeycombing which means interconnected voids arising from, for example, inadequate compaction or lack of mortar.

COR No. 2/2003(May)

TESTING: MATERIALS FOR JOINTS

Batch: joint filler, joint sealant	10.65	A batch of joint filler or joint sealant shall comply with Clause 16.89.
Samples: joint filler, joint sealant	10.66	Samples of joint filler or joint sealant shall comply with Clause 16.90.
Testing: joint filler, joint sealant	10.67	Testing of joint filler and joint sealant for joints in concrete carriageways shall be as stated in Clauses 16.91 and 16.92 except as stated in Clause 10.68.
Testing: joint sealant	10.68	Each sample of joint sealant shall be tested to determine the application life, tack-free time, resistance to flow, recovery, adhesion and cohesion in tension and compression and resistance to heat ageing. The method of testing shall be in accordance with BS 5212.

APPENDIX 10.1

DETERMINATION OF THE TEXTURE DEPTH OF CARRIAGEWAYS

Scope

10.1.1 This method covers the determination of the texture depth of carriageways by the sand patch test.

Materials

10.1.2 The following material is required:

Dry natural sand, with a rounded particle shape, which has been washed and then screened such that it meets the grading stated in Table 10.1.1.

Table 10.1.1: Grading of sand

BS test sieve	Percentage by mass passing
600 μm	100
300 μm	95 - 100
150 μm	0 - 6

Apparatus

10.1.3 The following apparatus is required:

(a) A soft brush.

(b) A robust measuring cylinder having an internal diameter of 20 ± 2 mm and a flat top surface such that its internal volume is 25 ± 0.1 mL.

(c) A flat wooden disc of 65± 2 mm diameter with a 1.5 mm minimum thickness hard rubber disc attached to one face and a handle fixed to the other face.

(d) A steel rule calibrated to 1 mm.

(e) A suitable wind shield.

(f) A funnel with an outlet tube at least 100 mm long with a bore of between 4 mm and 6 mm, and capable of accepting a volume of at least 200 mL.

(g) A steel straight edge for screeding off the measuring cylinder.

(h) A steel-wire brush.

Procedure

10.1.4 The procedure shall be as follows:

(a) The test location shall be at least 300 mm square. It shall be vigorously brushed ten times in two directions at right angles using the steel wire brush, and then dried and swept clean with the soft brush.

(b) Sand shall be poured into the measuring cylinder to fill it to overflowing, and any excess sand shall be screeded off using the straight edge. All sand on the outside of the cylinder shall be removed, taking care not to drop any sand onto the test location. Alternatively, this step in the procedure may be carried out in a laboratory, and the sand transferred to a suitable container ready for pouring.

(c) The measured volume of sand shall be poured onto the centre of the test location through the funnel to form a heap. The wind shield shall be used to protect the test location if required.

(d) The sand shall be spread outwards with a circular motion over the test location, using the rubber-faced disc with its face parallel to the surface of the carriageway. This shall be continued until the patch of sand is approximately circular and will spread outwards no more.

(e) The size of the circular patch of sand shall be measured to the nearest 1 mm along three diameters which are aligned at approximately 120 degrees to each other.

(f) If the difference between the maximum and minimum of the three measurements exceeds 20% of the average of the three measurements, then all the measurements shall be discarded and the test repeated at an adjacent location.

(g) The test shall be repeated for all the ten test locations for each Section of carriageway lane.

Calculation 10.1.5 (1) The texture depth (T) for each test shall be calculated from the equation:

$$T = 31000 / D^2 \text{ mm}$$

where:

- D is the average of the three diameter measurements of the sand patch calculated to the nearest 1 mm.

(2) The average texture depth for the ten tests shall be calculated.

Reporting of results 10.1.6 The following shall be reported:

(a) The test location.

(b) The average diameter of the sand patch for each test to the nearest 1 mm.

(c) The texture depth for each test to the nearest 0.1 mm.

(d) The average texture depth to the nearest 0.1 mm.

(e) That the test was carried out in accordance with this Specification.

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 11

MISCELLANEOUS ROADWORKS

SECTION 11

MISCELLANEOUS ROADWORKS

PART 1: GENERAL REQUIREMENTS

GENERAL

General requirements	11.01	The works and materials specified in Clauses 11.02 to 11.08 shall comply with the sections stated, unless otherwise stated in this Section.
Earthworks	11.02	Earthworks shall comply with Section 6.
Sub-base material and bituminous materials	11.03	Sub-base material and bituminous materials shall comply with Section 9.
Joints in concrete	11.04	Joints in concrete shall comply with Section 10.
Formwork	11.05	Formwork and finishes to concrete shall comply with Section 14.
Reinforcement	11.06	Steel reinforcement shall comply with Section 15.
Concrete	11.07	Concrete shall comply with Section 16.
Steelwork	11.08	Steelwork shall comply with Section 18.

MATERIALS

Cement mortar	11.09	Cement mortar shall consist of one part of cement to three parts of fine aggregate by volume together with the minimum amount of water necessary to achieve a consistency suitable for the required work. Fine aggregates shall be sand or crushed rock to BS 1200 and shall pass a 5 mm BS test sieve.
Polyethylene sheeting	11.10	Polyethylene sheeting shall be impermeable and shall have a nominal thickness of 0.125 mm.

PART 2: CONCRETE PROFILE BARRIERS

MATERIALS

Concrete mix 11.11 Concrete for concrete profile barriers shall be Grade 30/20.

SUBMISSIONS

Particulars of concrete profile barriers 11.12 (1) The following particulars of the proposed methods of construction for concrete profile barriers shall be submitted to the Engineer:

(a) particulars of formwork as stated in Clause 14.21 for in-situ construction using fixed forms,

(b) details of slip-form machine for in-situ construction between sliding forms, and

(c) methods of manufacture, handling, transport, storage and fixing in position of precast units.

(2) The particulars shall be submitted to the Engineer for information at least 14 days before construction of concrete profile barriers starts.

TRIALS

Trial length 11.13 (1) A trial length of concrete profile barrier shall be constructed to demonstrate that the proposed materials, mix design, methods of production and methods of construction will produce a concrete profile barrier which complies with the specified requirements. If it is not stated in the Contract that the trial length is to be constructed in a location separate from the permanent concrete profile barrier, the trial length shall be the first 25 m of the permanent barrier.

(2) The trial length shall be constructed in sufficient time before the permanent barrier is constructed to allow the Engineer a period of at least 7 days to determine if the specified requirements have been produced in the trial length.

(3) The Contractor shall inform the Engineer at least 24 hours, or such shorter period agreed by the Engineer, before constructing the trial length.

(4) The trial length shall be constructed using the materials, mix design, methods of production and methods of construction submitted to the Engineer.

(5) The trial length shall be used as a means of comparison against which the Engineer shall determine the compliance or otherwise of the permanent concrete profile barrier. The trial length shall be protected from damage and shall be left in position unless the Engineer instructs its removal. A trial length which forms part of the permanent barrier and which complies with the specified requirements shall not be removed.

Testing: trial length

11.14 (1) The trial length shall be tested to determine the accuracy of the alignment and level and the finish of the concrete surface.

(2) Concrete cores shall be cut from the trial length to determine the amount of segregation of the constituents and the presence of voids. The method of taking, preparing, inspecting and testing concrete cores shall be as stated in Clause 11.26.

Compliance criteria: trial length

11.15 The results of tests on trial lengths shall comply with the following requirements:

(a) The alignment and levels of the barrier shall comply with Clause 11.25.

(b) The finish of concrete surfaces shall comply with Clause 14.44.

(c) The amount of segregation of the constituents and the presence of voids shall comply with Clause 10.64 for concrete carriageways.

Non-compliance: trial length

11.16 (1) If the result of any test on the trial length does not comply with the specified requirements for the trial length, particulars of proposed changes to the materials, mix design, methods of production or methods of construction shall be submitted to the Engineer; further trial lengths shall be constructed until the result of every test on the trial length complies with the specified requirements for the trial length. Further trial mixes shall be made unless in the opinion of the Engineer non-compliance of the trial length was not due to the concrete mix.

(2) Unless otherwise permitted by the Engineer, trial lengths, or parts of trial lengths, which do not comply with the specified requirements for the trial length shall be removed.

Commencement of concreting

11.17 (1) Except as stated in Clause 11.17(2) concrete shall not be placed in the permanent barriers until the result of every test on the trial length complies with the specified requirements for the trial length.

(2) Concrete may be placed in the permanent barriers before the results of tests for compressive strength of the trial mix are available provided that the result of every other test on the trial mix and trial length complies with the specified requirements for trial mix concrete and for the trial length.

Changes in materials and methods of construction

11.18 Unless permitted by the Engineer, the materials, mix design, methods of production and methods of construction used to produce a trial length which complies with the specified requirements shall not be changed. Further trial lengths shall be constructed to demonstrate any proposed changes unless otherwise permitted by the Engineer.

FORMWORK AND FINISHES TO CONCRETE

Formwork 11.19 (1) Formwork for concrete profile barriers shall be steel unless otherwise permitted by the Engineer.

(2) Formwork shall not be loosened or removed until at least 7 hours after concreting has been completed.

Finishes to concrete 11.20 (1) The finish to unformed concrete surfaces of concrete profile barriers shall be Class U5.

(2) The finish to concrete surfaces for transverse joints shall be Class F3 and the finish to exposed concrete surfaces shall be Class F5.

JOINTS IN CONCRETE PROFILE BARRIERS

Joints in concrete profile barriers 11.21 (1) Joints shall be formed in concrete profile barriers at locations which coincide with expansion or construction joints in the adjoining structure or carriageway or at intervals not exceeding 12 m, whichever is less.

(2) Joints in concrete profile barriers shall comply with Section 16.

CONSTRUCTION OF CONCRETE PROFILE BARRIERS

Construction by slip-form machine 11.22 Construction of concrete profile barriers by slip-form machine between sliding forms shall be carried out in accordance with BS 5931. Slip-form machines shall comply with BS 5931, Appendix A.

Construction using precast units 11.23 Precast concrete profile barriers shall be laid on a cement mortar regulating layer of between 10 mm and 40 mm thick.

PROTECTION OF CONCRETE PROFILE BARRIERS

Protection of concrete profile barriers 11.24 Immediately after the formwork has been removed or the curing compound has been applied, concrete profile barriers shall be protected by polyethylene sheeting for at least 24 hours from exposure to conditions which may affect the concrete. The sheeting shall be lapped and securely held in position in such a manner that the surface of the concrete will not be damaged.

TOLERANCES

Tolerances: concrete profile barriers

11.25 Concrete profile barriers shall comply with the following requirements:

(a) The horizontal dimensions of cross-sections shall be within 5 mm of the specified dimensions.

(b) The vertical dimensions of cross-sections shall be within 10 mm of the specified dimensions.

(c) The horizontal alignment along the centreline shall be within 10 mm of the specified centreline.

(d) The level of the formation shall be within 10 mm of the specified level.

(e) The level of the top of the barriers shall be within 10 mm of the specified level.

(f) The barriers shall form a smooth alignment.

TESTING: CONCRETE CORES FROM TRIAL LENGTHS

Testing: concrete cores from trial lengths

11.26 (1) Two concrete cores shall be provided from each trial length of concrete profile barriers. The positions from which the cores are taken shall be as instructed by the Engineer.

(2) Samples, testing and compliance criteria for concrete cores from trial lengths shall be as stated in Clauses 10.62 (2) to (4), 10.63 and 10.64 for concrete carriageways.

PART 3: PEDESTRIAN GUARD-RAILING

GENERAL

Design of pedestrian guard-railing 11.27 Pedestrian guard-railing which is proposed by the Contractor as an alternative to that stated in the Contract or which is erected as Temporary Works shall be designed in accordance with BS 3049, Table 1, Class C.

MATERIALS

Steel 11.28 Steel for pedestrian guard-railing shall comply with the following:

Hot finished seamless tubes	: BS 6323: Part 3
Steel tubes and tubulars suitable for screwing to BS 21 pipe threads	: BS 1387
Hot rolled sections	: BS 4: Part 1
Hot rolled structural steel sections - equal and unequal angles	: BS 4848: Part 4
Weldable structural steels	: BS 4360.

Stainless steel 11.29 Stainless steel for pedestrian guard-railing shall be Grade 316 S 31 and shall comply with the following:

General inspection and testing procedures and specific requirements for carbon, carbon manganese and stainless steels	: BS 970: Part 1
Stainless steel tubes suitable for threading in accordance with BS 21	: BS 6362.

.

Aluminium

11.30 (1) Aluminium for pedestrian guard-railing shall be H 30 TF and shall comply with the following:

Wrought aluminium and aluminium alloys for general engineering purposes	
- plate, sheet and strip	: BS 1470
- drawn tube	: BS 1471
- bars, extruded round tubes and sections	: BS 1474.

(2) Aluminium shall be anodised to Grade AA 25 in accordance with BS 1615.

Bolts, nuts, screws, washers and rivets

11.31 (1) Bolts, nuts, screws, washers and rivets for pedestrian guard-railing shall comply with the following:

ISO metric black hexagon bolts, screws and nuts	: BS 4190
ISO metric black cup and countersunk head bolts and screws with hexagon nuts	: BS 4933
Metal washers for general engineering purposes	: BS 4320
Rivets for general engineering purposes	: BS 4620
Wrought aluminium and aluminium alloys for general engineering purposes	
- rivet, bolt and screw stock	: BS 1473.

(2) The length of bolts shall be such that the threaded portion of each bolt projects through the nut by at least one thread and by not more than four threads.

(3) Rag, indented and expansion bolts and resin bonded bolts shall be proprietary types approved by the Engineer and shall be capable of withstanding the design loading.

(4) Galvanized bolts, nuts, screws, washers and rivets shall be used with galvanized pedestrian guard-railing. Aluminium materials shall be insulated from ferrous materials by a non-conductive insulator at least 2 mm thick of a type approved by the Engineer.

Mesh infill 11.32 Mesh infill for pedestrian guard-railing shall comply with BS 4483. The mesh infill shall be free from surface defects, surface irregularities and mesh misalignment.

FABRICATION OF PEDESTRIAN GUARD-RAILING

Galvanizing to steel 11.33 (1) Steel components forming pedestrian guard-railing shall be hot-dip galvanized in accordance with BS 729 to a coating thickness of at least 500 g/m^2.

(2) Galvanizing to steel shall be applied after welding, drilling and cutting are complete.

Welding steel 11.34 (1) Welding for fabrication of pedestrian guard-railing shall be fillet welds. Welded surfaces shall be clean and flush before application of the protective coating.

(2) Steel shall not be welded after galvanizing unless permitted by the Engineer; if permitted, the welded areas shall be free from scale and slag and shall be treated with an alternative zinc-coating system approved by the Engineer.

SUBMISSIONS

Particulars of pedestrian guard-railing 11.35 (1) The following particulars of the proposed pedestrian guard-railing shall be submitted to the Engineer:

(a) a certificate from the manufacturer showing the manufacturer's name, the date and place of manufacture and showing that the materials comply with the requirements stated in the Contract, and

(b) details of alternative designs proposed by the Contractor, including drawings, showing the proposals and that the pedestrian guard-railing has been designed in accordance with Clause 11.27.

(2) The particulars shall be submitted to the Engineer at least 28 days before fabrication of the pedestrian guard-railing starts.

Samples of materials 11.36 Samples of the following proposed materials shall be submitted to the Engineer for approval of the source and type of each material at the same time as particulars of the pedestrian guard-railing are submitted:

(a) each type of pedestrian guard-railing,

(b) mesh infill, and

(c) each type of bolt, nut, and washer.

STORAGE OF MATERIALS

Storage of pedestrian guard-railing

11.37 Pedestrian guard-railing shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to the guard-railing or in contamination of the guard-railing. Pedestrian guard-railing shall be protected from damage and damaged guard-railing shall not be used in the permanent work unless permitted by the Engineer.

INSTALLATION OF PEDESTRIAN GUARD-RAILING

Installation of pedestrian guard-railing

11.38 (1) Pedestrian guard-railing shall be installed to a smooth alignment to within 10 mm of the specified position and height.

(2) Pedestrian guard-railing which is to be installed to a radius of less than 45 m shall be curved in the workshop and shall not be made up of a series of straight lengths.

(3) Pedestrian guard-railing shall be fixed to concrete using rag, indented, expansion or resin bonded bolts and shall be bolted to metalwork. Bolts for fixing to concrete shall be fitted into pockets filled with cement mortar or resin grout.

PART 4: UNTENSIONED BEAM BARRIERS

MATERIALS

Beams

11.39 (1) Beams for untensioned beam barriers shall be formed from steel plates complying with BS 1449: Part 1, type BHR, Grade 43/25.

(2) The beams shall be capable of withstanding a tensile force of at least 300 kN and shall not deflect by more than 40 mm when loaded centrally with a point load of 1 t over a simply supported span of 3 m.

(3) Beams shall comply with the following requirements:

(a) The base metal thickness shall be within 0.2 mm of the specified thickness.

(b) The strip width shall be within + 2.5 mm and - 0 mm of the specified width.

(c) The camber of the strip length shall be within 8 mm of the specified camber.

(d) The beam shall be straight to within 1.5 mm in a 1.5 m length.

(e) Angles at bends shall be within 2° of the specified angle.

(4) Bolt slots in beams for connection to posts shall be prepared in the workshop by cold saw-cutting. The spacing of the slots shall be such that posts will be spaced at either 4 m or 2 m.

(5) Beams shall be hot-dip galvanized in accordance with BS 729 to a coating thickness of at least 460 g/m^2.

(6) Welds for end beam sections shall be full-penetration butt welds.

Posts

11.40 (1) Posts for untensioned beam barriers shall be formed from Grade 43A steel complying with BS 4360.

(2) Posts shall be hot-dip galvanized in accordance with BS 729 to a coating thickness of at least 610 g/m^2.

(3) Posts fabricated from hollow sections shall be sealed by welding mild steel sealing plates over the open ends; the plates shall be at least 3 mm thick.

(4) Posts shall be within the tolerances stated in BS 4.

Cleats and struts

11.41 (1) Cleats and struts for untensioned beam barriers shall be fabricated from angle sections complying with BS 4 and shall be weldable structural steel complying with BS 4360, Grade 43A.

(2) Cleats and struts shall be hot-dip galvanized in accordance with BS 729 to a coating thickness of at least 610 g/m^2

(3) The dimensional tolerances of steel angles for cleats and struts shall comply with BS 4.

Bolts and nuts

11.42 (1) Bolts for untensioned beam barriers shall be M 16 size and strength Grade 4.6 complying with BS 4190. Bolts for beam splicing, bolts for connecting beams to posts and bolts for connecting beams to cleats shall be round or button-headed with oval shoulders; other bolts shall be ISO metric black hexagon type.

(2) Nuts for untensioned beam barriers shall be strength Grade 4 or 5 complying with BS 4190.

(3) Bolts and nuts shall be hot-dip galvanized in accordance with BS 729 to a coating thickness of at least 375 g/m^2.

(4) Nuts shall be tapped 0.4 mm oversize to accommodate the galvanized coating.

(5) The length of bolts shall be such that the threaded portion of each bolt projects through the nut by at least one thread and by not more than four threads.

(6) Rag, indented and expansion bolts and resin bonded bolts shall be proprietary types approved by the Engineer and shall be capable of withstanding the design loading.

Washers

11.43 (1) Washers for untensioned beam barriers shall be black mild steel and shall comply with BS 4320, Form E, F or G; washers shall be manufactured from steel complying with BS 1449: Part 1, Grade 250.

(2) Plain washers shall be 2 mm thick and shall be of dimensions suitable for use with M 16 bolts and nuts.

(3) Plain washers shall be hot-dip galvanized in accordance with BS 729 to a coating thickness of at least 375 g/m^2.

(4) Shaped washers shall have a thickness of at least 5 mm and shall be cast iron complying with BS 3468; the washers shall be shaped to fit the curvature of circular hollow sections used as posts.

SUBMISSIONS

Particulars of untensioned beam barriers

11.44 (1) The following particulars of the proposed materials and methods of construction for untensioned beam barriers shall be submitted to the Engineer:

(a) a certificate from the manufacturer for beams in the format stated in BS 4360 showing the manufacturer's name, the date and place of manufacture and showing that the beams comply with the requirements stated in the Contract and including carbon equivalent values, and

(b) details of method of installation.

(2) The particulars, including certificates, shall be submitted to the Engineer for approval of the source and type of materials at least 14 days before installation of the beams starts. Certificates shall be submitted for each batch of beams delivered to the Site.

Samples of materials

11.45 Samples of the following proposed materials shall be submitted to the Engineer for approval of the source and type of each material at the same time as particulars of the material are submitted:

(a) beams,

(b) posts, cleats and struts, and

(c) bolts, nuts and washers.

STORAGE OF MATERIALS

Storage of beams and posts

11.46 Beams and posts for untensioned beam barriers shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to the beams and posts or in contamination of the beams and posts. Beams and posts shall be protected from damage and damaged beams and posts shall not be used in the permanent work unless permitted by the Engineer.

CONSTRUCTION OF UNTENSIONED BEAM BARRIERS

Installation of untensioned beam barriers

11.47 (1) Untensioned beam barriers shall be ready for assembly when delivered to Site. Beams and posts shall be free from blisters, flux, uncoated spots and other defects.

(2) Untensioned beam barriers shall be installed to a smooth alignment to within 10 mm of the specified position and height. Transition sections shall provide a smooth and uniform transition.

(3) Beams which are to be installed to a radius of less than 45 m shall be curved in the workshop.

(4) Untensioned beam barriers shall be fixed to concrete using rag, indented, expansion or resin bonded bolts and shall be bolted to metalwork. Bolts for fixing to concrete shall be fitted into pockets filled with cement mortar or resin grout.

Compacted earth footings

11.48 (1) Sub-base material shall be deposited and compacted in the bottom 250 mm of pits for foundations of untensioned beam barriers with compacted earth footings. Fine fill material shall be deposited and compacted to the remainder of the pit. The sub-base material and fill material shall be compacted to obtain a relative compaction of at least 95% throughout.

(2) Posts for untensioned beam barriers shall be securely fixed in position during deposition and compaction of fill material.

Concrete footings

11.49 (1) Concrete for concrete footings shall be Grade 20/20.

(2) The top surface of concrete footings shall be finished level with the adjoining ground; the finish to the concrete surface shall be Class U5.

(3) Posts shall be surrounded with polyethylene sheeting before concrete is placed and shall be securely fixed in position during concreting.

Anchor blocks

11.50 (1) Concrete for anchor blocks shall be Grade 20/20.

(2) The finish to concrete surfaces of anchor blocks shall be Class F5 for formed finishes and Class U5 for unformed finishes.

PART 5: KERBS, EDGINGS AND QUADRANTS

MATERIALS

Concrete kerbs, edgings and quadrants

11.51 (1) Concrete for kerbs, edgings and quadrants shall be Grade 30/20. Concrete for foundations and backings to kerbs, edgings and quadrants shall be Grade 20/20.

(2) Precast concrete kerbs, edgings and quadrants shall comply with BS 7263: Part 1 except that the requirement for testing of water absorption shall not be applied. The nominal length of kerbs shall be 1 m and the nominal length of edgings shall be 750 mm.

Granite kerbs, edgings and quadrants

11.52 (1) Granite kerbs, edgings and quadrants shall be worked straight or circular. Corners shall be square and the top front and back edges shall be parallel. The length of granite kerbs and edgings shall be at least 600 mm.

(2) The ends of the kerbs, edgings and quadrants shall be chisel-dressed square to form a close butt-joint with adjacent kerbs. Kerbs shall be chisel-dressed to a depth of at least 140 mm on the front face, at least 75 mm on the back face and for the full width of the top face.

CONSTRUCTION OF KERBS, EDGINGS AND QUADRANTS

Construction of precast concrete and granite kerbs, edgings and quadrants

11.53 (1) Precast concrete and granite kerbs, edgings and quadrants shall be laid and bedded on a regulating layer of cement mortar; the thickness of the layer shall be at least 10 mm and shall not exceed 40 mm.

(2) Except as stated in this clause, joints between each kerb, edging and quadrant shall not exceed 10 mm in width and shall be filled and flush pointed with cement mortar. Joints in kerbs, edgings and quadrants at expansion joints on bridge decks shall be as stated in the Contract. Transverse expansion and contraction joints in kerbs, edgings and quadrants laid on or adjacent to concrete carriageways shall be in accordance with Clause 10.35(2).

(3) Radius kerbs shall be used for curves less than 10 m external radius.

Construction of in-situ kerbs, edgings and quadrants

11.54 (1) In-situ concrete kerbs, edgings and quadrants shall be constructed in accordance with BS 5931 and shall be laid by an automatic extrusion machine of a type approved by the Engineer.

(2) In-situ concrete kerbs, quadrants and edgings shall have regular sides, edges, arrises and chamfers; the finish to the concrete surface shall be Class U5. Kerbs, edges and quadrants shall not be finished or dressed with cement mortar.

(3) Contraction joints shall be formed at intervals not greater than approximately 4 m. Transverse expansion and contraction joints in kerbs, edgings and quadrants which are laid on or adjacent to concrete carriageways shall be in accordance with Clause 10.35(2). Joints shall be flush pointed with cement mortar.

TOLERANCES

Tolerances: kerbs, edgings and quadrants	11.55	(1) The line of kerbs, edgings and quadrants shall be within 3 mm of the specified line. (2) The level of the top of kerbs, edgings and quadrants shall be within 3 mm of the specified level.

PART 6: FOOTWAYS, CYCLETRACKS AND PAVED AREAS

MATERIALS

Concrete for footways, cycletracks and paved areas

11.56 Concrete for footways, cycletracks and paved areas shall be Grade 30/20.

CONSTRUCTION OF FOOTWAYS, CYCLETRACKS AND PAVED AREAS

In-situ concrete footways, cycletracks and paved areas

11.57 In-situ concrete for footways, cycletracks and paved areas shall be laid in areas not exceeding 20 m^2. The finish to the concrete surface shall be Class U4.

Flexible surfacing to footways, cycletracks and paved areas

11.58 (1) Bituminous materials for footways, cycletracks and paved areas shall be laid and compacted with steel-wheeled and pneumatic-tyred rollers. Compaction shall start before the temperature of the newly laid material falls below 100^0C and shall continue until all roller marks have been removed. For locations where rollers cannot operate effectively, the bituminous material can be compacted by hand-operated mechanical compaction plant approved by the Engineer.

(2) Cores shall be taken in accordance with GS Clause 9.58 for the checking of air void content and compacted layer thickness of the bituminous material for works with area of not less than $200m^2$. For works with area smaller than $200m^2$ but greater than $50m^2$, at least 2 cores shall be taken from each layer of bituminous material laid. For works with area less than $50m^2$, no coring is required unless otherwise instructed by the Engineer.

(3) The cores taken in accordance with GS Clause 11.58(2) shall be tested to determine the air void content. The average air void content of the cores shall be not less than 3% nor greater than 9%. If the test result does not comply with the specified requirement, 2 additional cores shall be taken at locations agreed by the Engineer and the average air void content determined from these 2 cores shall replace the original value for compliance checking. Notwithstanding this, no cores shall have an air void content of less than 2.5% nor greater than 10%.

(4) Each core taken from the final surfacing layer shall also be measured to determine the compacted layer thickness that shall not deviate by more than 5mm from the specified thickness. If the measured thickness does not comply with the requirement, 2 additional cores shall be taken at locations agreed by the Engineer and the average thickness determined from these 2 cores shall replace the original measured value for compliance checking.

(5) If no bulk sample is taken for determination of the Rice's specific gravity, the corresponding value obtained from the mix design shall be used in determining the air void content of the core unless other value is suggested by the Contractor and agreed by the Engineer.

(6) If either the air void content or the compacted thickness of the core is outside the specified limits, the sub-area from which the cores were taken shall be considered as not complying with the requirements specified in this clause.

PROTECTION OF FOOTWAYS, CYCLETRACKS AND PAVED AREAS

Protection of footways, cycletracks and paved areas 11.59 Footways, cycletracks and paved areas shall not be used by Constructional Plant or vehicles other than those which in the opinion of the Engineer are essential to construct the subsequent work.

PART 7: PRECAST CONCRETE PAVING SLABS AND INTERLOCKING BLOCKS

GLOSSARY OF TERMS

Unit 11.60 Unit is a term used to describe a precast concrete paving slab or interlocking block.

MATERIALS

Paving slabs and interlocking blocks 11.61 (1) Concrete for precast concrete paving slabs shall be Grade 30.

(2) Concrete for precast concrete interlocking blocks in footways and cycletracks shall be Grade 30; concrete for precast concrete interlocking blocks in carriageways or areas to which vehicles will have access shall be Grade 45.

(3) The nominal maximum aggregate size of aggregate for concrete in precast units shall be 10 mm.

(4) The dimensions of the precast units shall be within 3 mm of the specified dimensions; chamfers shall not exceed 8 mm.

(5) Paving slabs shall be square or rectangular and interlocking blocks shall be rectangular unless otherwise selected in the Contract.

(6) The colour of precast units shall be consistent over the area to be paved.

Sand 11.62 (1) Sand for bedding precast units shall have the particle size distribution stated in Table 11.1. The sand shall have a moisture content exceeding 4% and not exceeding 8% at the time of laying.

(2) Sand for filling joints between precast units shall have the particle size distribution stated in Table 11.2. The sand shall have a moisture content of less than 0.5% at the time of filling joints.

Table 11.1: Particle size distribution of sand for bedding precast units

BS test sieve size	Percentage by mass passing
10 mm	100
5 mm	85 - 100
2.36 mm	65 - 100
1.18 mm	40 - 98
600 μm	25 - 72
300 μm	10 - 35
150 μm	0 - 15
75 μm	0 - 10

Table 11.2: Particle size distribution of sand for filling joints between precast units

BS test sieve size	Percentage by mass passing
2.36 mm	100
1.18 mm	90 - 100
600 μm	60 - 90
300 μm	30 - 60
150 μm	15 - 30
75 μm	5 - 10

SUBMISSIONS

Particulars of units 11.63 (1) The following particulars of the proposed materials and methods of construction for paving slabs and interlocking blocks shall be submitted to the Engineer:

(a) name and address of manufacturer,

(b) a certificate from the manufacturer showing the manufacturer's name and the date and place of manufacture and including results of tests for:
- compressive strength of concrete cubes at 28 days
- compressive strength of interlocking blocks, and

(c) drawings showing the layout of the units within the paved area.

(2) The particulars shall be submitted to the Engineer for approval of the source and type of the units and for approval of the layout of the units at least 14 days before laying of the units starts.

Samples of materials 11.64 Samples of each type of unit shall be submitted to the Engineer for approval of the source and type of each unit at the same time as particulars of the unit are submitted.

HANDLING AND STORAGE OF MATERIALS

Handling and storage of units 11.65 Units shall be handled and stored on pallets to avoid damage to corners and chamfer edges. Pallets shall be stored on a level base and in a manner which will not result in damage to the units or in contamination of the units. The units shall be protected from damage and damaged units shall not be used unless permitted by the Engineer.

Storage of sand 11.66 Sand for filling joints between units shall be stored in waterproof bags and shall be kept under cover until used.

LAYING PAVING SLABS AND INTERLOCKING BLOCKS

Laying units 11.67 (1) Paving slabs and interlocking blocks shall not be laid until the layout of the units within the paved area has been approved by the Engineer.

(2) Kerbs and edgings shall be completed before the units are laid; the compressive strength of the concrete used for in-situ concrete kerbs and edgings shall be at least 20 MPa before units are laid.

(3) Measures shall be taken to prevent water draining across or through the area during laying, bedding and compaction of the units.

(4) Laying of units shall start as soon as practicable after the formation has been completed. The formation shall be protected as stated in Clause 6.52 until laying starts.

(5) Interlocking blocks for carriageways and paved areas to which vehicles will have access shall be laid in a herring-bone pattern unless otherwise stated in the Contract.

(6) Units shall be cut to size where required using mechanical cutting devices. The cut edge shall be similar to that of an uncut unit and shall be true to line and free from chips and cracks.

Laying sand 11.68 (1) A layer of sand shall be laid and shall be screeded and tamped to a uniform depth over the complete width of the area to be paved. The quantity of sand shall be sufficient to permit screeding to waste and to achieve a tamped thickness which exceeds 20 mm and does not exceed 30 mm.

(2) The sand layer shall not be disturbed by additional compaction, foot-marks or other damage after the layer has been screeded and tamped to the required level and before the units are laid.

(3) Sand shall not be screeded and tamped more than 1 m in advance of the units which have been laid.

Bedding paving slabs 11.69 (1) Paving slabs shall be laid on the prepared sand layer immediately after screeding and tamping in such a manner that the sand is not disturbed.

(2) Paving slabs shall be adjusted to form uniform joints between 2 mm and 3 mm wide and shall be bedded into the final position using a wooden mallet or a plate vibrator fitted with a rubber base-pad.

(3) Paving slabs shall not be bedded closer than 1 m behind the laying edge other than on completion of the paved area against a kerb or edging.

(4) Final levelling of the slabs shall be carried out as soon as practicable after bedding and before changes in the moisture content of the prepared sand layer occur.

(5) Damaged paving slabs shall be immediately removed and replaced.

Bedding interlocking blocks 11.70 (1) Interlocking blocks shall be laid on the prepared sand layer immediately after screeding and tamping in such a manner that the sand is not disturbed. Interlocking blocks shall be individually laid on the prepared sand layer by manual methods or in clusters by mechanical methods.

(2) Interlocking blocks shall be laid in such a manner that the blocks are not in direct contact with each other and that uniform joints of between 2 mm and 3 mm wide are formed. Interlocking blocks shall be bedded flush by at least two passes of a heavy-duty plate compactor fitted with a rubber base-pad.

(3) Interlocking blocks shall not be bedded closer than 1 m behind the laying edge other than on completion of the paved area against a kerb or edging.

(4) Final levelling of the blocks shall be carried out as soon as practicable after bedding and before changes in the moisture content of the prepared sand layer occur.

(5) Damaged interlocking blocks shall be immediately removed and replaced.

Filling joints and compaction of units

11.71 (1) After the units have been bedded, sand for filling the joints shall be spread over the surface of the units and brushed into the joints in such a manner that all joints are completely filled.

(2) Joints shall be filled as soon as practicable after bedding and on the day the units are laid and bedded.

(3) Paved areas shall be further compacted by at least two passes of a plate compactor fitted with a rubber base-pad after filling the joints to ensure that the joints are completely filled. Sand shall be added as required and compacted into the joints.

(4) Carriageways and paved areas to which vehicles will have access shall be compacted by at least ten evenly-spaced passes of a pneumatic tyred roller having a gross weight of between 10 t and 12 t. Sand shall be added as required and brushed and compacted into the joints.

(5) Excess sand shall be removed after completion of compaction.

(6) Damaged units shall be immediately removed and replaced.

Mortar and concrete seal

11.72 Pigmented mortar or concrete shall be placed to the full depth of the unit to form a seal between units and adjacent kerbs, edgings, quadrants, covers, frames and other hardware. The pigment shall match the colour of the adjacent units.

REINSTATEMENT OF UNITS

Reinstatement of units

11.73 (1) If excavation is to be carried out in paved areas constructed using paving slabs or interlocking blocks, the units shall be extracted by manual methods for a distance of at least 300 mm beyond the limit of the excavation.

(2) Unbroken units shall be thoroughly cleaned to remove all sand and deleterious material. The units shall be stacked on pallets for re-use.

(3) Units to be re-used shall be re-laid in accordance with Clauses 11.67 to 11.72.

TOLERANCES

Tolerances: paving slabs and interlocking blocks

11.74 The level of paved areas constructed using paving slabs or interlocking blocks shall be within 3 mm of the specified level. The difference in level of adjacent slabs shall not exceed 2 mm.

TESTING: CHARACTERISTIC COMPRESSIVE STRENGTH OF INTERLOCKING BLOCKS

Batch: interlocking blocks

11.75 A batch of interlocking blocks is any quantity of interlocking blocks of the same type and size, of the same concrete grade, manufactured in the same place, covered by the same certificates and delivered to the Site at any one time.

Samples: interlocking blocks

11.76 (1) One sample of each type of interlocking blocks shall be provided from every 1000 interlocking blocks or part thereof.

(2) The number of interlocking blocks in each sample shall be five.

Testing: interlocking blocks

11.77 (1) Each sample of interlocking blocks shall be tested to determine the characteristic compressive strength at 28 days.

(2) The method of testing shall be as stated in Appendix 11.1.

Compliance criteria: interlocking blocks

11.78 The characteristic compressive strength of a sample of interlocking blocks shall be:

(a) 30 MPa for blocks in footways and cycletracks, and

(b) 45 MPa for blocks in carriageways and paved areas to which vehicles will have access.

APPENDIX 11.1

DETERMINATION OF CHARACTERISTIC COMPRESSIVE STRENGTH OF INTERLOCKING BLOCKS

Scope

11.1.1 This method covers the determination of the characteristic compressive strength at 28 days of interlocking blocks by means of a load test.

Apparatus

11.1.2 The following apparatus is required:

(a) A compression test machine complying with CS1. Bearing faces of the platens on the test machine shall be at least as large as the interlocking blocks and shall have a flatness tolerance of 0.05 mm.

(b) If a test machine with platens smaller than the interlocking blocks is used, auxiliary plates of adequate size shall be placed centrally between the platens and the interlocking block to be tested. The flatness tolerance of the bearing faces of the auxiliary platens measured in accordance with CS1 shall not be more than 0.05 mm and the thickness of the plates shall be at least 25 mm.

(c) Two pieces of packing, each with a thickness of between 5 mm and 6 mm and dimensions exceeding the interlocking block by between 15 mm and 25 mm. The packing shall be plywood, chipboard or medium density hardboard.

Procedure

11.1.3 The procedure shall be as follows:

(a) The interlocking block shall be capped on the running surface and underside with a suitable capping material in accordance with Clause 15.5.2 of CS1 and immersed in water for at least 24 hours before compression.

(b) The interlocking block shall be placed symmetrically on the lower platen of the test machine, between the two pieces of packing with the running surface facing upwards.

(c) Load shall be applied without shock and shall be steadily increased at a constant rate within a stress range of between 150 kPa/s and 700 kPa/s.

(d) The load at which the interlocking block fractures shall be recorded as the breaking load.

(e) The test shall be repeated for the other four blocks.

Calculation 11.1.4 (1) The compressive strength (C) of each interlocking block shall be calculated from the equation:

$$C = \frac{W}{A} \times \frac{2.5}{1.5 + \frac{L}{H}} \quad \text{MPa}$$

where:

- W is the breaking load (N)
- A is the nominal gross plan area based on the manufacturing dimensions of the interlocking blocks or the area of the tested portion if the interlocking block size is reduced for testing (mm^2)
- L is the lesser of the two plan dimensions (mm)
- H is the thickness of the block (mm)

(2) The unbiased standard deviation (s) shall be calculated from the following equation:

$$s = \frac{\sqrt{\sum C^2 - 5(Cm)^2}}{2} \quad \text{MPa}$$

where:

- $\sum C^2$ is the sum of the square of the compressive strengths of the five interlocking blocks (MPa)
- Cm is the average of the compressive strengths of the five interlocking blocks

(3) The characteristic strength (Cc) of the batch shall be calculated from the following equation:

$$Cc = Cm - 1.65s \quad \text{MPa}$$

where:

- Cm is the average of the compressive strengths of the five interlocking blocks as stated in Clause 11.1.4(2)
- s is the unbiased standard deviation as stated in Clause 11.1.4(2)

Reporting of results 11.1.5 The following shall be reported:

(a) Source, name of manufacturer and type of blocks.

(b) Identification marks of blocks.

(c) Date of manufacture of blocks.

(d) Nominal gross plan area of each block to the nearest 100 mm^2.

(e) Nominal height of each block to the nearest mm.

(f) Breaking load of each block to the nearest kN.

(g) Compressive strength of each block to the nearest MPa.

(h) Average of the five compressive strengths to the nearest MPa.

(i) Unbiased standard deviation to the nearest MPa.

(j) Characteristic compressive strength to the nearest MPa.

(k) That the test method used was in accordance with this Specification.

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 12

TRAFFIC SIGNS, ROAD MARKINGS AND ROAD STUDS

SECTION 12

TRAFFIC SIGNS, ROAD MARKINGS AND ROAD STUDS

PART 1: TRAFFIC SIGNS

GENERAL

General requirements 12.01 The works and materials specified in Clauses 12.02 to 12.03 shall comply with the sections stated, unless otherwise stated in this Section.

Temporary traffic arrangements and control 12.02 Temporary traffic arrangements and control shall comply with Section 1.

Steelwork 12.03 Steelwork shall comply with Section 18.

Traffic signs 12.04 (1) Traffic signs shall comply with the Road Traffic Ordinance, Cap 374 and its subsidiary legislation. Traffic signs for road tunnels shall comply with the Road Tunnels (Government) Ordinance, Cap 368 and its subsidiary legislation.

(2) The design of traffic signs, including letters, characters, numbers, symbols and borders, shall be in accordance with conditions and restrictions imposed by the Commissioner for Transport.

(3) Traffic signs shall comply with the following:

Internally illuminated signs and external lighting luminaires	: BS 873: Part 5
Retroreflective and non-retroreflective signs	: BS 873: Part 6
Posts and fittings	: BS 873: Part 7

except that the requirements for marking signs shall not apply.

(4) Traffic signs shall be externally illuminated, internally illuminated, retroreflective, non-retroreflective or a combination of these types as stated in the Contract.

MATERIALS

Steel 12.05 Steel for traffic signs shall comply with the following:

Hot finished seamless tubes	: BS 6323: Part 3
Hot rolled sections	: BS 4: Part 1

Hot rolled structural steel sections		
- equal and unequal angles	: BS 4848: Part 4	
Weldable structural steels	: BS 4360	

Stainless steel 12.06 Stainless steel for traffic signs shall be Grade 304 S 11 and shall comply with the following:

General inspection and testing procedures and specific requirements for carbon, carbon manganese and stainless steels	: BS 970: Part 1
Stainless steel tubes suitable for threading in accordance with BS 21	: BS 6362

Aluminium 12.07 (1) Aluminium for traffic signs shall be H 30 TF and shall comply with the following:

Wrought aluminium and aluminium alloys for general engineering purposes	
- plate, sheet and strip	: BS 1470
- drawn tube	: BS 1471
- bars, extruded round tubes and sections	: BS 1474

(2) Aluminium shall be anodised to Grade AA 25 in accordance with BS 1615.

(3) Aluminium sheet shall be free from twisting, warping and buckling and the surfaces shall be free from blemishes and other defects.

Bolts, nuts, screws, washers and rivets 12.08 (1) Bolts, nuts, screws, washers and rivets for traffic signs shall comply with the following:

ISO metric black hexagon bolts, screws and nuts	: BS 4190
ISO metric black cup and countersunk head bolts and screws with hexagon nuts	: BS 4933
Metal washers for general engineering purposes	: BS 4320
Rivets for general engineering purposes	: BS 4620
Wrought aluminium and aluminium alloys for general engineering	

purposes
- rivet, bolt and screw stock : BS 1473

General inspection and testing procedures and specific requirements for carbon, carbon manganese and stainless steels : BS 970: Part 1

(2) The length of bolts shall be such that after assembly the threaded portion of each bolt projects through the nut by at least one thread and by not more than four threads.

(3) Rag and indented bolts shall comply with BS 1494: Part 2. Expansion bolts and resin bonded bolts shall be a proprietary type approved by the Engineer and shall be capable of withstanding the design working load.

(4) Galvanised bolts, nuts, screws, washers and rivets shall be used with traffic signs secured to galvanised pedestrian guard-railing. Aluminium materials shall be insulated from ferrous materials by a non-conductive insulator at least 2 mm thick of a type approved by the Engineer.

Materials for faces of traffic signs 12.09 (1) Retroreflective sheeting shall be Class 1 or Class 2 material complying with BS 873: Part 6, Tables 1 and 2.

(2) Non-retroreflective sheeting shall comply with BS 873: Part 6.

(3) Plastic sheeting shall be a proprietary type approved by the Engineer.

(4) All materials and finishes shall be mutually compatible.

FABRICATION OF TRAFFIC SIGNS

Posts for traffic signs 12.10 (1) Posts for beacons at zebra crossings shall be painted with alternate black and white stripes. Other posts shall be painted grey in accordance with BS 5252F, Code 18B19 or shall be galvanized in accordance with BS 729.

(2) Galvanised areas affected by cutting and drilling shall be treated using a method approved by the Engineer.

(3) Posts other than posts supporting an external luminaire shall not protrude above the top of signs. The length of posts supporting external luminaries protruding above the top of signs shall be as short as practicable.

Backing plates for traffic signs

12.11 (1) Backing plates for traffic signs shall be fabricated from 3 mm aluminium sheet. Backing plates for traffic signs not exceeding 1200 mm high x 2400 mm wide shall be fabricated from a single sheet. If more than one sheet is used, the number of sheets shall be kept to a minimum; the separate sheets shall be rectangular and shall be approximately the same size.

(2) Holes in backing plates shall be drilled before the plate is painted and before retroreflective or non-retroreflective sheeting is applied.

Spill screens for traffic signs

12.12 (1) Top and bottom light spill screens shall be fabricated from the same material as the backing plate. The spill screens shall extend for the complete width of the backing plate and the corners shall be cut to the same radius as the corners of the backing plate.

(2) Spill screens shall be considered as part of the backing plate and stiffeners and mountings shall be designed to accommodate the combined size.

Faces for traffic signs

12.13 (1) Faces for traffic signs shall be formed using retroreflective or non-retroreflective plastic sheeting. Unless otherwise permitted by the Engineer, a single piece of sheeting shall be used. If more than one sheet is used, the number of sheets shall be kept to a minimum. Sheeting shall be fixed in accordance with the manufacturer's recommendations.

(2) Materials for faces of traffic signs, including the background, letters, characters, numerals, symbols and borders, shall be matched for colour in accordance with the sheeting manufacturer's recommendations at the time of fabrication to provide a uniform appearance by day and by night.

(3) Letters, characters, numerals, symbols and borders shall be clear cut and sharp-edged and shall have no cracks.

(4) Sheeting material, including letters, characters, numerals, symbols and borders shall be fully fixed using adhesive; there shall be no air bubbles, creases, cracks or other blemishes.

Lacquer coatings

12.14 Lacquer coatings to faces for traffic signs shall be uniform and continuous and shall be applied at the time of manufacture of the face.

Painting to faces for traffic signs

12.15 (1) Faces of traffic signs to which a painted or stoved finish is to be applied shall be thoroughly cleaned and pre-treated before painting and stoving.

(2) Pre-treatment shall be by anodising or by using an etching primer or by a process approved by the Engineer.

(3) At least one undercoat and at least one finishing coat of paint shall be applied and stoved to a thickness of between 0.0315 mm and 0.0375 mm of enamel over a minimum thickness of 0.025 mm of primer. If light colours are to be applied over dark colours, at least two coats of the light colour shall be applied. The final surface shall have a uniform thickness and an egg-shell flat finish and shall be smooth and free from defects.

(4) The colours of the finished coating shall be uniform. The colours, including white, shall comply with the chromaticity co-ordinates of BS 873: Part 6, Table 4 and, for comparative purposes, shall comply with the following gloss paint colours in accordance with BS 381C:

- red : No. 537 - signal red,
- orange : No. 557 - light orange,
- yellow : No. 355 - lemon yellow,
- blue : No. 109 - middle blue,
- green : No. 225 - light brunswick green

(5) Parts of faces coloured black shall be non-retroreflective and shall have a luminance factor not exceeding 0.05 as measured in accordance with BS 873: Part 6.

SUBMISSIONS

Particulars of traffic signs 12.16 (1) The following particulars of the proposed traffic signs shall be submitted to the Engineer:

(a) name of manufacturer, and

(b) details of materials and finishes to be used in the manufacture of the signs.

(2) The particulars shall be submitted to the Engineer at least 14 days before fabrication of traffic signs starts.

STORAGE OF MATERIALS

Storage of traffic signs 12.17 (1) Traffic signs shall be stored in a dry, weatherproof store. Traffic signs which are stored together shall be separated by slip sheets.

(2) Traffic signs shall be stored in a manner which will not result in damage or deformation to the signs.

CONSTRUCTION AND ASSEMBLY OF TRAFFIC SIGNS

Construction and assembly of traffic signs 12.18 (1) Fittings for traffic signs shall be non-corrodible material approved by the Engineer.

(2) Joints for framework and stiffeners which are not an integral part of the backing plate shall be welded or joined using brackets, nuts, bolts and washers.

(3) Materials for rivets and other fixings for joining backing plates to framework and stiffeners shall be compatible with the materials to be joined. The spacing of rivets and other fixings shall be uniform; the spacing shall not exceed 150 mm around the outside edge of sheets and shall not exceed 300 mm on cross braces.

(4) An additional washer of neoprene, nylon or other material approved by the Engineer shall be used to protect the faces of traffic signs from metal nuts, bolts, washers and screws.

(5) Backing plates shall be connected to posts by a method approved by the Engineer. Banding systems shall be stainless steel. Drilling of holes in ferrous components shall be completed before finishes are applied.

(6) A lacquer coating shall be applied to the edges of holes drilled in plates with plastic sheeting immediately before rivets and bolts are inserted. The surfaces of rivets and bolts on the faces of traffic signs shall be covered with a material coloured to match the part of the face with which it is in contact.

(7) Fixings for traffic signs erected on road lighting columns shall be compatible with the column cross section; columns shall not be drilled.

Covering of traffic signs

12.19 (1) Traffic signs which are to be blanked out shall be covered by the following methods:

(a) Plate signs shall be covered using a 1.5 mm thick sheet which is compatible with the material in the sign.

(b) Plate signs which are to be blanked out for a period not exceeding one year may alternatively be covered using a self-adhesive plastic film.

(c) Other signs shall be covered using a loose cover sheet of material approved by the Engineer.

(2) Cover sheets shall be fixed using 5 mm diameter stainless steel bolts, washers and nuts or non-ferrous rivets at spacings not exceeding 600 mm. Bolts shall pass through 5 mm x 12 mm diameter plastic distance pieces between the face of the sign and the cover plate. Holes which remain on the finished face of the sign shall be filled using blocked rivets; the face of the rivets shall be coloured by a method approved by the Engineer.

(3) Self-adhesive plastic film shall be compatible with the material in the face of the sign and shall be fixed and removed in accordance with the manufacturer's recommendations.

(4) Loose covers shall be securely fastened to the back of the sign. Tape or other adhesive material shall not be applied to the faces of signs.

(5) Coverings to traffic signs shall be sufficiently opaque to prevent reflection from the covered sign and shall not be removed until the Engineer so instructs.

(6) Unless otherwise permitted by the Engineer, the faces of traffic signs which have been erected and which do not relate either wholly or in part to the traffic situation which applies at that time shall be blanked out as stated in this Clause.

TESTING: TRAFFIC SIGNS

Testing: 12.20 (1) The number of traffic signs to be tested shall be as stated in the Contract or as instructed by the Engineer.

(2) The number and type of tests to be carried out on the traffic signs shall be as stated in the Contract as instructed by the Engineer.

(3) Testing shall be carried out in such a manner that the traffic sign will not be damaged.

(4) Testing shall be carried out by the Contractor at a laboratory approved by the Engineer.

Compliance criteria: 12.21 The compliance criteria for testing traffic signs shall be in accordance with BS 873: Part 1.

PART 2: ROAD MARKINGS

GLOSSARY OF TERMS

Road Markings 12.22 Road markings are white or yellow continuous or intermittent lines, letters, characters, figures, arrows or symbols marked on the carriageway to guide road users and pedestrians.

MATERIALS

Hot applied thermoplastic material 12.23 (1) Hot applied thermoplastic material shall comply with BS 3262: Part 1 except that:

(a) the softening point measured in accordance with BS 3262: Part 1, Appendix E, shall not be less than 85ºC, and

(b) the flow resistance shall be such that a cone made and tested in accordance with BS 3262: Part 1 shall not slump by more than 25% after 48 hours at 40ºC ±2ºC.

(2) Solid glass beads shall be included in the supplied mixture of hot applied thermoplastic material.

(3) Binder for thermoplastic material shall be synthetic hydrocarbon resin or natural resin based as stated in the Contract.

Cold applied preformed material 12.24 (1) Cold applied preformed material for road markings shall be a proprietary type approved by the Engineer

(2) Solid glass beads shall be applied to cold applied preformed material at the place of manufacture.

Paint for road markings 12.25 Paint for road markings shall comply with BS 6044.

Solid glass beads 12.26 Solid glass beads shall comply with BS 6088, Class B.

SUBMISSIONS

Particulars of road markings 12.27 (1) The following particulars of the proposed materials for road markings shall be submitted to the Engineer:

- certificates for thermoplastic material, paint and solid glass beads showing the manufacturer's name, the date and place of manufacture and showing that the material complies with the requirements stated in the Contract and including results of tests for softening point and flow resistance of thermoplastic material.

(2) The particulars shall be submitted to the Engineer at least 14 days before the relevant work starts.

DELIVERY AND STORAGE OF MATERIALS

Delivery and storage of thermoplastic material 12.28 Hot applied thermoplastic material shall be delivered and stored in accordance with BS 3262: Part 1, Clauses 9 and 10 and the manufacturers recommendations.

Storage of preformed material 12.29 Cold applied preformed material shall be stored in accordance with the manufacturer's recommendations.

LAYING ROAD MARKINGS

Preparation of surfaces 12.30 (1) Road markings shall not be laid over loose detritus, mud or similar extraneous matter. Oil and grease shall be removed from the surface of carriageways on which road markings will be laid.

(2) Curing compound shall be removed from the surface of new concrete carriageways on which road markings will be laid, by wire brushing or by other methods agreed by the Engineer.

(3) Existing road markings which are to be replaced by a different type of material shall be removed by high pressure water jetting, shot blasting, rotary grinding or by other methods agreed by the Engineer; the existing markings shall not be masked using black paint or similar methods.

(4) Existing road markings which are to be renewed using a similar type of material shall be roughened by a method agreed by the Engineer until the thickness of the existing material is reduced by approximately 50%.

(5) A tack coat shall be applied to the surface of concrete carriageways before hot thermoplastic material is laid. The tack coat shall be compatible with the road marking material and shall be applied in accordance with the manufacturer's recommendations.

(6) Rotary grinding machines shall not be used to remove or roughen existing road markings within 100 mm of longitudinal or transverse joints on concrete carriageways.

Laying hot applied thermoplastic material 12.31 (1) Hot applied thermoplastic material shall be prepared and laid in accordance with BS 3262: Part 3, Clauses 4 and 5. The material shall not be laid when the surface of the carriageway is wet, or the air ambient temperature in the shade is less than 10°C.

(2) Hot applied thermoplastic material shall be laid by machine or by screeding methods. The machine or apparatus shall be capable of producing a marking to a uniform thickness and width; the marking shall have clean edges and shall be free from streaks and blisters.

(3) The thickness of road markings, not including surface applied solid glass beads, shall comply with the following:

(a)	screed markings	: 4 mm
(b)	sprayed lines other than yellow edge lines	: ≥ 1.5 mm

(c) sprayed yellow edge lines : ≥ 0.8 mm

The thickness shall be measured in accordance with BS 3262: Part 3, Appendix B.

Laying cold applied preformed material 12.32 (1) Cold applied preformed material shall be laid in accordance with the manufacturer's recommendations. The material shall not be laid when the surface of the carriageway is wet.

(2) The thickness of road markings shall be at least 1.5 mm

Use of road marking paint 12.33 Unless permitted by the Engineer, road marking paint shall not be used other than for temporary road markings.

Reflectorisation 12.34 Solid glass beads shall be applied to the surface of hot applied thermoplastic material and road marking paint immediately after the material or paint has been applied, to enhance the reflectivity of the surface. The solid glass beads shall be uniformly applied by a mechanical method at a rate of between 400 g/m^2 and 500 g/m^2.

Temporary road markings 12.35 (1) Temporary road markings shall be used at locations instructed by the Engineer. Cold applied preformed material shall be used for temporary road markings which are to be removed.

(2) Temporary road markings shall be disposed of by the Contractor after removal. All traces of tape shall be removed from the surface of the carriageway and existing permanent road markings shall be made good such that in the opinion of the Engineer it is safe to allow traffic to use the road.

Skid resistance level 12.36 The skid resistance level of road markings measured in accordance with BS 3262: Part 1 shall be at least 45.

TOLERANCES

Tolerances 12.37 The lengths, thicknesses and widths of hot applied thermoplastic material road markings shall comply with the following requirements:

(a) The thickness of screed markings shall be within 1 mm of the specified thickness.

(b) The length and width of screed markings and sprayed lines shall be within +10%, -5% of the specified dimension.

PART 3: ROAD STUDS

MATERIALS

Road studs 12.38 (1) Road studs shall comply with the Road Traffic Ordinance, Cap 374 and its subsidiary legislation.

(2) Road studs shall be a proprietary type approved by the Engineer.

(3) Permanent reflecting road studs to be used as lane line markers on dual carriageway trunk roads and primary distributor roads shall be a type to which traffic cylinders of a type approved by the Engineer can be attached. The method of attachment shall be such that the traffic cylinder can be easily detached from the road stud.

(4) Temporary reflecting road studs to be used as markers for temporary traffic routes shall be yellow.

Bitumen grout 12.39 (1) Bitumen grout for road studs shall consist of bitumen and filler. The bitumen content shall be 25% to 30% of the total mass.

(2) Bitumen shall be tropical grade filled bitumen, oxidised Grade R 85/25.

(3) Filler shall be hydrated lime; the percentage by mass of hydrated lime passing a 75 μm BS test sieve shall be at least 85%.

(4) The properties of bitumen grout for road studs shall comply with the following requirements:

(a) The penetration at 25°C shall be 12±4.

(b) The softening point shall be 105°C ± 5°C.

(c) The specific gravity shall not exceed 1.80.

INSTALLATION OF ROAD STUDS

Installation of road studs 12.40 (1) Road studs shall be installed in accordance with the manufacturer's recommendations.

(2) Depressible road studs shall be installed using bitumen grout.

(3) Road studs shall not be installed on concrete carriageways until the concrete has reached the specified grade strength.

(4) Surfaces to which bonded road studs are to be fixed shall be clean and all dust, grease and other deleterious material shall be removed immediately before the studs are installed.

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 13

WORK FOR ELECTRICAL AND MECHANICAL INSTALLATIONS

SECTION 13

WORK FOR ELECTRICAL AND MECHANICAL INSTALLATIONS

GENERAL

General requirements 13.01 The works and materials specified in Clauses 13.02 and 13.03 shall comply with the sections stated, unless otherwise stated in this Section.

Earthworks 13.02 Earthworks shall comply with Section 6.

Materials for grout 13.03 Materials for grout shall comply with Section 16.

GLOSSARY OF TERMS

Concealed electrical conduit system 13.04 Concealed electrical conduit system is an electrical conduit system, including all bends, couplers, bushes, saddles, boxes, covers, plugs, draw wires and other conduit fittings, which is cast into concrete or fixed in chases in brickwork with a minimum cover of 20 mm or which is laid directly in the ground.

MATERIALS

Electrical conduits and fittings 13.05 (1) Electrical conduits and fittings shall comply with BS 4568: Parts 1 and 2 and shall have Class 4 heavy protection inside and outside. Conduits shall be heavy gauge with screw-end construction in steel and shall have an external diameter of at least 20 mm; conduits shall be longitudinally welded.

(2) Metal boxes for enclosing electrical accessories shall comply with BS 4662 and shall have heavy protection inside and outside; the boxes shall be of preferred sizes and shall be 35 mm or 47 mm deep as appropriate. Circular ceiling boxes of deep pattern shall comply with BS 4568: Part 2 and shall have Class 4 heavy protection inside and outside; the boxes shall be at least 60 mm deep internally.

(3) Circular boxes, dome covers and hook covers shall be cast iron. Bushes and plugs shall be brass.

Cable ducts and fittings 13.06 (1) UPVC cable ducts for installation above ground or for casting into concrete shall be Class 0 UPVC pipes complying with BS 3506. Cable ducts for installation below ground shall be Class B UPVC pipes complying with BS 3506.

(2) Joints and fittings for use with UPVC cable ducts shall comply with BS 4346: Part 1 and BS 4346: Part 2. Solvent cement for UPVC pipes and fittings shall comply with BS 4346: Part 3.

(3) Steel cable ducts shall be steel tubes complying with BS 1387, medium series, screwed and socketed tubes and shall have screwed sockets suitable for screwing to BS 21, Table 2 pipe threads. The tubes, sockets, clamps and saddles for ducts shall be galvanized in accordance with BS 729.

Paint for conduit and duct systems 13.07 (1) Bituminous paint for steel conduits and steel cable ducts shall comply with BS 3416, type 1.

(2) Anti-rust paint for concealed electrical conduit systems shall be a proprietary type approved by the Engineer.

(3) Zinc chromate primer for cable duct systems shall comply with BS 4652.

(4) Galvanizing paint for cable duct systems shall be a proprietary type approved by the Engineer.

Fire barriers 13.08 Internal fire barriers shall be a type offering adequate fire resistance for the application. The material shall be approved by the Engineer in compliance with Fire Services Department requirements and shall be resistant to fire, smoke, gas and water.

Cement grout for electrical and mechanical installations 13.09 The different types of cement grout for electrical and mechanical installations shall consist of ordinary Portland cement, sand and PFA in the proportions by mass stated in Table 13.1 together with the minimum amount of water necessary to achieve a consistency suitable for completely filling the voids; the mix shall contain a non-shrink admixture.

Table 13.1: Mix proportions of cement grout

Type	Mix proportions by mass		
	Cement	Sand	PFA
G1	1	-	-
G2	1	3	-
G3	1	10	-
G4	1	-	7

STORAGE OF MATERIALS

Storage of materials for conduit and cable duct systems 13.10 Materials for concealed electrical conduit systems and for cable duct systems shall be stored in accordance with the manufacturers' recommendations in a dry weatherproof store.

HOLES AND RECESSES FOR ELECTRICAL AND MECHANICAL INSTALLATIONS

Holes and recesses for electrical and mechanical installations

13.11 (1) Holes and recesses shall be left in structures for electrical and mechanical installations. If instructed by the Engineer, holes and recesses shall be cut in structures for electrical and mechanical installations.

(2) Holes and recesses in internal floors, stairways and platforms shall be protected with temporary covers or by other methods agreed by the Engineer until the electrical and mechanical installation starts; holes and recesses in roofs, external walls and external floors shall be sealed with watertight temporary covers until the electrical and mechanical installation starts.

(3) Holes in structures shall be filled and made good after electrical and mechanical installations are complete; holes left in structural elements designated as fire barriers shall be sealed to at least the same degree of fire resistance as the structural element.

FIRE BARRIERS

Fire barriers

13.12 Internal fire barriers shall be constructed in service channels, service shafts and service ducts for electrical and mechanical installations at the following locations:

(a) at points of interSection with structural elements designated as fire barriers,

(b) at 5 m centres in vertical and inclined shafts, and at intersections with floor slabs, and

(c) at termination points and open ends.

CONCEALED ELECTRICAL CONDUIT SYSTEMS

Construction of conduit systems

13.13 (1) Concealed electrical conduit systems which are shown diagrammatically in the Contract shall be constructed as stated in Clause 13.13(2) to (7).

(2) Concealed electrical conduit systems shall be mechanically and electrically continuous and shall be effectively earthed.

(3) Principal conduit runs shall be either vertical or horizontal. Tee pieces and elbows, including those with provision for inspection, shall not be used unless approved by the Engineer.

(4) Joints shall be made using coupler units into which the ends of the conduits shall be inserted and tightened. Running couplings shall not be used unless permitted by the Engineer; if permitted, the couplings shall be made by screwing each of the conduits half way into the coupler with a hexagonal lock nut against each end of the coupler.

(5) Adaptable boxes shall be provided at:

(a) every second bend,

(b) after a bend and a straight run of 10 m or less, and

(c) every 15 m in straight runs.

(6) Adaptable boxes for conduits installed in floor screeds shall have the lids set flush with the adjacent floor; the boxes shall be covered with the same material as the remainder of the floor and shall remain accessible at all times.

(7) The clearance between conduits entering adaptable boxes and between adjacent or parallel conduits shall be at least the nominal maximum coarse aggregate size of the concrete plus 5 mm.

Installation of conduit systems

13.14 (1) Concealed electrical conduit systems shall be arranged and installed in accordance with best trade practice and in such a manner that all cables can be drawn with ease and without damage.

(2) Bends in concealed electrical conduit systems shall be formed by using proprietary bending equipment of a type agreed by the Engineer; connections and other work shall be carried out using purpose made equipment.

(3) Conduits shall not be bent by more than 90^0 and the internal radius at bends shall be at least 2.5 times the external diameter of the conduit. Conduits shall not be flattened at bends.

(4) Burrs and sharp edges shall be removed from the ends of conduits before installation.

(5) Concealed electrical conduit systems which are to be cast into concrete shall be fastened to the reinforcement with tying wire of the same type used for the reinforcement. The conduit systems shall not be positioned between the reinforcement and the outside face of the concrete unless permitted by the Engineer.

(6) Conduit boxes shall be of a compatible size and shall have a single extension ring of the required depth if the plaster finish exceeds 13 mm thick; multiple extension rings shall not be used.

Terminations of conduit systems

13.15 Screw fitting couplers shall be provided at each end of conduits which terminate in distribution boards, busbar chambers, motor starters, cable ducts, boxes or similar termination points. The item at which the conduit terminates shall be drilled with an unthreaded clearance hole to receive a brass male bush; the bush shall be screwed into the coupler from the inside of the item in such a manner that the surface of the item is gripped between the coupler and the bush. The threads shall be at least half the length of the coupler.

Protection of conduit systems

13.16 (1) Concealed electrical conduit systems shall have special arrangements designed by the Contractor to permit movement of conduits to take place on each side of movement joints in structures. A separate circuit protective conductor shall be installed to maintain effective electrical continuity across the joint. The protective conductor shall have a cross-sectional area rated to suit the largest live conductor to be drawn into the conduit.

(2) Steel conduit systems laid in contact with or adjacent to other metal work shall have efficient and permanent metallic connection made between the conduit and the metal work.

(3) Underground steel conduits and conduits in contact with soil shall be painted with two coats of bituminous paint before installation.

(4) Exposed threads and damage to protective coatings of conduit systems shall be painted with two coats of anti-rust paint.

(5) Conduits shall be laid in such a manner that accumulation of condensed moisture in the conduit system is prevented; measures shall be taken to prevent water from entering the system.

(6) Water, moisture and deleterious material shall be prevented from entering permanent and temporary terminations in concealed electrical conduit systems, including conduit boxes, by using conduit stopping plugs of a type approved by the Engineer; paper or rags shall not be used.

Cleaning of conduit systems

13.17 After installation, concealed electrical conduit systems shall be swabbed out with draw-in tapes and absorbent cloth of a type agreed by the Engineer; all obstructions shall be removed and draw wires shall be installed. After cleaning, exposed conduit ends shall be sealed as stated in Clause 13.16(6).

CABLE DUCT SYSTEMS

Installation of cable duct system

13.18 (1) Changes in direction in cable duct systems shall be constructed in such a manner that the cables in the duct will have radii of curvature of at least 800 mm. Ducts entering draw-in pits shall be on the same horizontal plane as the draw-in pit.

(2) UPVC cable ducts shall be jointed in accordance with the manufacturer's recommendations.

(3) Steel cable ducts shall be jointed using screwed galvanized sockets and spun yarn or by an equivalent method approved by the Engineer such that the jointed pipes abut; the threads shall be painted with two coats of bituminous paint. Internal rags and burrs shall be removed to provide a smooth bore through joints in the cable duct system.

(4) Surface mounted cable ducts shall be secured by galvanised steel clamps or saddles at spacings not exceeding 3 m.

Protection of cable duct systems

13.19 (1) After jointing, exposed bare metal in cable duct systems shall be cleaned and painted with two coats of zinc chromate primer and two coats of galvanizing paint.

(2) Surface mounted galvanized steel cable ducts shall be cleaned and painted after fittings and jointing have been completed.

Cleaning of cable duct systems 13.20 After jointing, cable duct systems shall be cleaned internally by scrubbing with a cylindrical brush of a type agreed by the Engineer. The ends of ducts, including ends of ducts in draw-in pits and spare ducts, shall be fitted with tapered hardwood plugs to prevent water, moisture and deleterious material from entering the system and a 6 mm diameter nylon draw line shall be installed. The plugs shall be centrally drilled for the draw line and the draw line shall be secured by a knot tied on the outer face of the plug to leave at least 1500 mm of surplus line at each plug.

ELECTRICAL EARTHING SYSTEMS

Electrical earthing systems 13.21 (1) Pits and trenches for electrical earthing systems shall be excavated at positions and at the times instructed by the Engineer.

(2) After the electrical earthing systems have been installed fill material shall be deposited and compacted in the pits and trenches to a depth of 300 mm above the electrical earthing system. Fill material shall be sand or fine fill material which has been selected from the excavated material, and which is free from stones retained on a 20 mm BS test sieve. Fill material shall be compacted by handrammers in a manner approved by the Engineer.

GROUTING FOR ELECTRICAL AND MECHANICAL INSTALLATIONS

Grouting for electrical and mechanical installations 13.22 (1) Grouting to structural steelwork, machine bases, crane rails, electrical and mechanical equipment and other electrical and mechanical installations shall comply with the requirements stated in Clause 13.22(2) to (8).

(2) Grouting shall be carried out at the times instructed by the Engineer and shall be completed within 7 days of the instruction unless otherwise permitted by the Engineer.

(3) The permission of the Engineer shall be obtained before items or equipment are grouted. The Contractor shall inform the Engineer 3 days, or such shorter period agreed by the Engineer, before grouting starts and shall allow the Engineer sufficient time to inspect the work which is to be grouted.

(4) Concrete surfaces shall be scabbled to remove laitance and loose material and to expose the aggregate before the item or equipment is installed in position.

(5) The voids to be grouted shall be cleaned and thoroughly wetted immediately before grouting. Excess water shall be removed by using a compressed air jet or by other methods agreed by the Engineer.

(6) Grout shall be mixed and placed by methods agreed by the Engineer.

(7) If grouting is to be carried out in two operations, holding down bolts shall be grouted into preformed pockets and sufficient time shall be allowed for the grout to cure and for the bolts to be tensioned before the remaining voids are grouted.

(8) Exposed grout surfaces shall have a uniform, dense and smooth surface free from trowel marks and which is produced by steel trowelling the surface under firm pressure. The exposed surfaces shall be cured by either:

(a) using a liquid curing compound applied to the surface by a low-pressure spray until a continuous visible covering is achieved, or

(b) covering the surface with hessian or sacking; the hessian or sacking shall be lapped and securely held in position and shall be kept damp for at least 4 days.

COMPLETION AND PROTECTION OF WORK FOR ELECTRICAL AND MECHANICAL INSTALLATIONS

Completion of work for electrical and mechanical installations

13.23 (1) Work shall be completed to the conditions stated in Clause 13.23(2) to (8) before structures are made available to others for electrical and mechanical installations.

(2) The structure shall be clean, dry and free from dust. Work which in the opinion of the Engineer will produce large quantities of dust shall be complete.

(3) Holes and recesses, concealed electrical conduit systems and cable duct systems required for the installation shall be complete. Concrete surfaces on which items and equipment are to be installed shall be scabbled.

(4) Plinths, trenches, louvres, openings and similar work shall be complete and shall have hardened sufficiently to allow the installation to proceed.

(5) Floors and slabs shall be complete to the specified finishes except that floor tiles shall not be laid until after the installation is complete.

(6) Plant rooms shall be complete, including fixtures and fittings, to a secure and weatherproof condition. Two sets of door keys for the plant room shall be provided for the Engineer.

(7) Paintwork and similar finishes in plant rooms shall be complete to undercoat level; final coats shall not be applied until after the installation is complete.

(8) Temporary power supplies and connections required for the installation shall be complete. The supply shall be metered and shall be a 346V, 3 phase supply of 20A maximum rating. Temporary power supplies shall be provided for the periods stated in the Contract.

Protection of work for electrical and mechanical installations

13.24 (1) Structures in which electrical and mechanical installations are being carried out shall be maintained in a clean, dry condition, free from dust, during the installation.

(2) The dust level in plant rooms shall be kept to a minimum by using industrial dust extractors of a type agreed by the Engineer during and after the installation. Temporary screens shall be installed to separate dust-

affected areas from the installations or temporary covers shall be installed around the installation.

TOLERANCES

Tolerances: floors of switchgear rooms

13.25 The tolerance in floor levels for switchgear rooms shall be as follows:

(a) ± 2 mm in 1000 mm for high voltage switchgear rooms,

(b) ± 4 mm in 1000 mm for medium voltage switchgear rooms.

Tolerances: lamp standards

13.26 Lamp standards shall be within 0.1 degrees of the vertical.

INSPECTION OF WORK FOR ELECTRICAL AND MECHANICAL INSTALLATIONS

Inspection of work for electrical and mechanical installations

13.27 (1) The Contractor shall allow the Engineer to inspect the following work for electrical and mechanical installations:

(a) completed concealed electrical conduit systems, cable duct systems, electrical earthing systems and items and equipment which are to be grouted or covered up,

(b) items and equipment which are to be tested, and

(c) structures which are to be made available for electrical and mechanical installations.

(2) The Contractor shall inform the Engineer three days, or such shorter period agreed by the Engineer, before work is covered up, tested or made available.

TESTING: EARTHING CONTINUITY

Testing: earthing continuity

13.28 (1) Concealed electrical conduit systems shall be tested to determine the earthing continuity. The system shall be tested:

(a) before the system is cast in concrete or covered up,

(b) after the system is cast in concrete or covered up, and

(c) after electrical wiring which is installed by the Contractor is complete.

(2) Unless otherwise approved by the Engineer the method of testing shall be in accordance with Appendix 15 to the IEE Wiring Regulations, 15th Edition, 1981 issued by the Institution of Electrical Engineers.

Compliance criteria: earthing continuity

13.29 The results of tests for earthing continuity shall comply with the IEE Wiring Regulations, 15th Edition, 1981 issued by the Institution of Electrical Engineers.

TESTING: LOAD TESTS ON BEAMS AND JOISTS

Testing: load tests on beams and joists

13.30 (1) Load tests shall be carried out on lifting beams, rolled steel joists and lifting hooks which are installed by the Contractor.

(2) Testing shall be carried out by an independent testing consultant approved by the Engineer and by using methods approved by the Engineer.

(3) A certificate showing the results of the load tests and signed by the testing agent shall be submitted to the Engineer within 14 days of the test.

Compliance criteria: load tests on beams and joists

13.31 The results of tests on lifting beams, rolled steel joists and lifting hooks shall comply with the Factories and Industrial Undertakings (Lifting Appliances and Lifting Gear) Regulations, 1978 issued by the Labour Department.

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 14

FORMWORK AND FINISHES TO CONCRETE

SECTION 14

FORMWORK AND FINISHES TO CONCRETE

GENERAL

General requirements	14.01	The works and materials specified in Clauses 14.02 and 14.03 shall comply with the sections stated, unless otherwise stated in this Section.
Concrete carriageways	14.02	Surface finish to concrete carriageways shall comply with Section 10.
Cover spacers	14.03	Cover spacers for steel reinforcement shall comply with Section 15.

GLOSSARY OF TERMS

Class	14.04	Class is a term used to identify the different types and standards of formed, unformed and treated finishes.
Falsework	14.05	Falsework is a temporary structure used to support formwork and a permanent structure until the permanent structure is self-supporting.
Formed finish	14.06	Formed finish is the finish of the concrete surface produced by the use of formwork.
Formwork	14.07	Formwork is the mould against which concrete is cast and which gives the shape and finish to the concrete surface.
Permanent formwork	14.08	Permanent formwork is formwork designed to remain in position as part of the permanent work.
Profiled formwork	14.09	Profiled formwork is formwork designed to produce a ribbed or patterned finish on the concrete surface.
Sealed plywood	14.10	Sealed plywood is plywood which has been sealed with a factory-applied film of phenolic resin or plastic material.
Spatterdash	14.11	Spatterdash is a mixture of cement, coarse sand, granite fines and water, used as a rendering on concrete surfaces.
Treated finish	14.12	Treated finish is the finish of the concrete surface produced by a treatment applied to a formed or unformed finish.
Unformed finish	14.13	Unformed finish is the finish of the concrete surface produced without formwork and by working the concrete surface before the concrete has hardened.

MATERIALS

Formwork

14.14 (1) Formwork shall be timber, metal, plastic or other material which will produce the specified finish. Materials used as formers for profiled formwork, chamfers, splays, rebates and other features shall be such that they produce the same finish as the main formwork.

(2) Plywood for formwork shall have a close, uniform grain and the edges shall be sealed with barrier paint, polyurethane varnish or other impermeable material.

(3) The faces of formwork for Class F4 and F5 finishes shall have a uniform texture and a matt, not a shiny or polished, surface. The edges of the formwork shall be straight and square.

Formwork Class of finish

14.15 (1) The characteristics of each class of finish shall be as stated in Tables 14.1, 14.2 and 14.3.

(2) Formwork of the type stated in Table 14.1 will normally produce a concrete surface which complies with the characteristics of finish stated in Table 14.1 but other types of formwork may be used to produce the specified finish.

(3) The Class of formed and unformed finish required for different concrete surfaces shall be as stated in Table 14.4 unless otherwise stated in the Contract. The higher Class of finish shall start at least 150 mm below the finished ground level for concrete surfaces which are partly buried.

Release agents

14.16 (1) Release agents shall be a proprietary type approved by the Engineer. Release agents containing mineral oils shall not be used. Barrier paint, polyurethane varnish, wax or other materials shall not be used instead of a release agent.

(2) Release agents shall be a type which will not stain or colour the concrete and which will not affect the bond between the concrete and subsequent coverings. Release agents other than those which incorporate a surface retarder to produce a Class T1 finish shall be a type which will not affect the hardening of the concrete.

(3) Release agents used on formwork for water retaining structures for potable and fresh water shall be non-toxic and shall not impart a taste to the water.

(4) Release agents used on steel formwork shall contain a rust-inhibiting agent.

(5) Release agents used on formwork for Class F4 and F5 finishes shall be a chemical release agent.

(6) On areas of formwork which in the opinion of the Engineer are likely to be affected by pedestrian traffic, rain or dust, release agents for Class F4 and F5 finishes shall be a type which evaporates to leave a dry film on the formwork, unless protection from such effects is provided.

Table 14.1: Formed finishes

Class of finish	Type of formwork normally used	Characteristics of finish			
		Formwork pattern	Abrupt irregularities permitted	Gradual irregularities permitted	Specific requirements
F1	Sawn timber	Not required	< 10 mm	< 15 mm in 2 m	No specific requirements
F2	Plywood	Pattern of formwork joints and tie holes as stated in Clause 14.30(1) and (2)	< 5 mm	< 10 mm in 2 m	Even surface No grout runs
F3			< 3 mm	< 5 mm in 2 m	Even surface No grout runs
F4	Sealed plywood				Uniform, dense and smooth surface No grout runs No grain pattern No crazing No major blemishes
F5			< 2 mm	< 3 mm in 2 m	Uniform, dense and smooth surface No grout runs No grain pattern No crazing No blemishes No staining or discolouration

Table 14.2: Unformed finishes

Class of finish	Method of producing finish	Characteristics of finish		
		Abrupt irregularities permitted	Gradual irregularities permitted	Specific requirements
U1	Levelling the surface of the compacted concrete with a screed board	Screed marks < 5 mm	< 10 mm in 2 m	No specific requirements
U2	Forming a Class U1 finish and tamping the surface	Tamp marks < 10 mm	Not applicable	Ridged surface
U3	Forming a Class U1 finish and wood floating or power floating the surface	Float marks < 3 mm	< 10 mm in 2 m	Uniform, dense and smooth surface
U4	Forming a Class U3 finish and brushing the surface with a stiff brush	Brush marks < 3 mm	< 10 mm in 2 m	Rough texture
U5	Forming a Class U3 finish and steel trowelling the surface under firm pressure or power floating the surface	Nil	< 5 mm in 2 m	Uniform, dense and smooth surface, free from trowel marks No staining or discolouration

Table 14.3: Treated finishes

<table>
<tr><th>Class of finish</th><th>Type of finish</th><th>Method of producing finish</th><th>Characteristics of finish</th></tr>
<tr><td>T1</td><td>Exposed aggregate</td><td>Washing and brushing the concrete surface</td><td>Cement matrix removed and coarse aggregate exposed to a depth not exceeding one-third of the nominal maximum coarse aggregate size</td></tr>
<tr><td>T2</td><td>Point tooled</td><td>Point tooling the concrete surface</td><td rowspan="2">Cement matrix and aggregate surface removed sufficiently to expose the aggregate with a minimum penetration into the matrix between aggregates</td></tr>
<tr><td>T3</td><td>Bush hammered</td><td>Bush hammering the concrete surface</td></tr>
<tr><td>T4</td><td>Broken rib</td><td>Hammering or chiselling the edges and faces of the concrete surface</td><td>Fragments of concrete ribs removed</td></tr>
<tr><td>T5</td><td>Light blasting</td><td rowspan="2">Blasting the concrete surface by abrasives and compressed air or by water jetting</td><td>Cement matrix removed and coarse aggregate exposed to a minimum depth</td></tr>
<tr><td>T6</td><td>Heavy blasting</td><td>Cement matrix removed and coarse aggregate exposed to a depth not exceeding one-third of the nominal maximum coarse aggregate size</td></tr>
</table>

Table 14.4: Class of finish

Description of surface		Class of finish	
		Formed	Unformed
Surfaces to be covered	- screeded	-	U2
	- rendered, plastered	F2	-
	- tiled	F2	U3
	- painted	F4	U5
Surfaces for treated finishes		F3	U3
Surfaces for pedestrian traffic		-	U4
Construction joints (for Class T1 finish)		F2	U3
Movement joints		F3	U3
Benching, screeds		F3	U5
Blinding, foundations, pile caps		F1	U1
Piers, blocks, pipe surrounds	- below FGL	F1	U1
	- above FGL	F2	U3
Manholes, chambers	- external below FGL	F1	U1
	- external above FGL	F2	U3
	- internal	F2	U3
Culverts, channels	- external below FGL	F1	U1
	- external above FGL	F2	U3
	- internal	F4	U5
Water retaining structures	- external below FGL	F2	U3
	- external above FGL	F4	U5
	- internal	F4	U5
Buildings	- external below FGL	F1	U1
	- external above FGL	F2	U3
	- internal	F4	U5
Bridges, retaining walls, walls	- below FGL	F1	U1
	- above FGL, not exposed to direct public view	F4	U5
	- above FGL, exposed to direct public view	F5	U5
	- internal, not exposed to direct public view	F2	U1

Formwork ties

14.17 (1) Formwork ties and components shall be a type such that any removable part can be removed without damaging the concrete; any part left in the concrete shall be at least 40 mm or the specified nominal cover to the reinforcement, whichever is greater, from the concrete surface.

(2) Unless otherwise permitted by the Engineer, formwork ties and components used with profiled formwork shall be a type such that holes left by the ties and components are small enough to be located completely within the recesses in the concrete surface.

Cement mortar for concrete surfaces

14.18 (1) Cement mortar for filling blowholes shall consist of cement and fine aggregate together with the minimum amount of water necessary to achieve a consistency suitable for completely filling the blowholes.

(2) Cement mortar for filling holes left by formwork ties and components shall consist of 1 part of cement to 3 parts of fine aggregate together with the minimum amount of water necessary to achieve a consistency suitable for compacting the mortar into the holes; the mix shall contain a non-shrink admixture.

(3) Cement mortar for filling blowholes and holes left by formwork ties and components in concrete surfaces with Class F4 and F5 finishes shall be the same colour as the hardened concrete; light-coloured sand or white cement may be used for this purpose.

(4) Materials for cement mortar shall comply with Section 16.

Surface retarders

14.19 Surface retarders shall be a proprietary type approved by the Engineer and shall be a type which will not stain or colour the concrete.

Abrasives

14.20 Abrasives for blasting shall be grit or other materials approved by the Engineer and shall not contain any iron, clay or other materials which will stain or colour the concrete.

SUBMISSIONS

Particulars of formwork and finishes to concrete and samples of materials

14.21 (1) Particulars and samples of the proposed materials and methods of construction for Class F4, F5, U5 and T finishes shall be submitted to the Engineer as marked 'x' in Table 14.5. The same particulars shall be submitted for other Classes of finish if required by the Engineer.

(2) The particulars and samples for formed finishes shall be submitted at least 14 days before the relevant formwork, including formwork for trial panels, is fabricated. The particulars and samples for unformed and treated finishes shall be submitted at least 14 days before the relevant element, including trial panels, is concreted.

Table 14.5: Particulars to be submitted

Particulars to be submitted		Formed finishes	Unformed finishes	Treated finishes
Formwork drawings	: Panel construction	X	-	X
	Layout and pattern of panels, joints and formwork ties	X	-	X
Method statement		-	X	X
Samples	: Formwork	X	-	-
	Formwork ties	X	-	X
	Cover spacers	X	-	X
Brand name and manufacturer's literature	: Release agent	X	-	X
	Curing compound	X	X	X
	Surface retarder	-	-	X
Programme	: Removing formwork	X	-	-
	Applying treated finishes	-	-	X
Details	: Sources of formwork, formwork ties and cover spacers	X	-	X
	Curing	X	X	X
	Filling blowholes	X	-	-
	Filling formwork tie holes	X	-	X
	Protecting finishes	X	X	X

TRIAL PANELS

Trial panels 14.22 (1) A trial panel shall be constructed for each Class F4, F5, U5 and T finish to demonstrate that the proposed materials, mix design, methods of production and methods of construction, including curing and removal of formwork, will produce the specified finish.

(2) Trial panels for Class F4 and F5 finishes shall be constructed before the relevant formwork for the permanent work is erected, and trial panels for Class U5 and T finishes shall be constructed before the relevant permanent work is concreted. The trial panels shall be constructed at least 4 weeks before the relevant permanent work is carried out.

(3) The Contractor shall inform the Engineer at least 24 hours, or such shorter period agreed by the Engineer, before constructing trial panels.

(4) Trial panels shall be constructed using the materials, mix design, methods of production and methods of construction, including curing and removal of formwork, submitted to the Engineer

(5) Trial panels shall be horizontal, vertical or inclined as appropriate and shall be constructed at locations agreed by the Engineer. Unless otherwise stated in the Contract each trial panel shall be not less than 2 m by 2 m by 300 mm thick, and shall contain reinforcement representative of the most congested reinforcement which will be used in the permanent work. Trial panels shall incorporate formwork ties and components, horizontal joints, vertical joints, chamfers, splays, rebates and other features representative of those which will be used in the permanent work.

(6) Trial panels shall be protected from damage and shall be left in position until the Engineer instructs their removal.

Non-compliance: trial panels 14.23 If in the opinion of the Engineer the specified finish has not been produced in the trial panel, particulars of proposed changes to the materials, mix design, methods of production or methods of construction shall be submitted to the Engineer; further trial panels shall be constructed until the specified finish is produced in the trial panel. Further trial mixes shall be made unless in the opinion of the Engineer non-compliance of the trial panel was not due to the concrete mix.

Commencement of formwork and concreting 14.24 Formwork for Class F4 and F5 finishes shall not be erected and elements with Class U5 and T finishes shall not be concreted until in the opinion of the Engineer the specified finish has been produced in the trial panel.

Changes in materials and methods of construction 14.25 Unless permitted by the Engineer, the materials, mix design, methods of production or methods of construction, including curing and removal of formwork, used to produce the specified finish in trial panels shall not be changed.

STORAGE OF MATERIALS

Storage of formwork 14.26 (1) Formwork shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to the formwork or in contamination of the formwork.

(2) Formwork for Class F4 and F5 finishes shall be covered and protected from exposure to conditions which may affect the formwork.

Storage of release agents and surface retarders 14.27 Release agents and surface retarders shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.

DESIGN AND CONSTRUCTION OF FALSEWORK AND FORMWORK

Design and construction of falsework and formwork 14.28 (1) Falsework and formwork shall be designed and constructed to maintain the position and shape of the formwork such that the hardened concrete surface complies with the characteristics of finish stated in Table 14.1 and with any more stringent tolerances stated in the Contract; allowance shall be made for cambers.

(2) Falsework and formwork shall be capable of being dismantled and removed without shock, disturbance, damage or loading to the concrete and in such a manner that the specified requirements for removing or leaving in position side formwork, soffit formwork and props will be achieved without disturbing other formwork or props.

(3) Formwork shall be used to form the top surface of concrete inclined at a slope exceeding 15^{o} to the horizontal unless it can be demonstrated that the specified finish will be produced without the use of formwork. Formwork to top surfaces shall be anchored to prevent flotation.

Construction of formwork

14.29 (1) Formwork shall not have any splits, cracks or other defects. The faces and edges of formwork shall be clean and formwork faces shall be free of projecting nails.

(2) Formwork which has been previously used shall be repaired and the edges resealed before it is erected. Formwork which in the opinion of the Engineer has deteriorated to an extent such that it will not produce the specified finish shall not be used for that Class or a higher Class of finish.

(3) Formwork shall be firmly supported and individual panels shall be rigid. Joints between formwork panels, stop ends and adjoining concrete shall be tight and shall not permit grout loss. Gaps shall be sealed with gaskets, filler, sealant or tape before the application of release agents.

(4) Formwork shall be cut in such a manner that reinforcement and built-in components passing through the formwork are maintained in position; the joints shall be tight and shall not permit grout loss.

(5) Formers for profiled formwork, chamfers, splays, rebates and other features shall be rigidly and evenly fixed to the formwork along the complete length and shall not permit grout loss.

(6) Formwork ties and components shall be fixed in such a manner that they do not touch reinforcement or built-in components. Formwork ties and components shall fit tightly against formwork faces and shall not permit grout loss.

(7) If required for cleaning or inspection, temporary openings shall be provided in the formwork.

Construction of formwork for Class F2, F3, F4 and F5 finishes

14.30 (1) Formwork panels for Class F2, F3, F4 and F5 finishes shall be the same size and shall form a regular pattern approved by the Engineer. The lines of joints between panels shall be straight and continuous, horizontal and vertical, or inclined to suit the pattern of profiled formwork, and shall be coincident with construction joints and other joints and with recesses in the concrete surface. The number of make-up pieces shall be kept to a minimum.

(2) Holes left by formwork ties and components in concrete surfaces with Class F2, F3, F4 and F5 finishes shall be in line horizontally and vertically and shall form a regular pattern approved by the Engineer. Unless otherwise permitted by the Engineer, holes in profiled formwork shall be located in such a manner that the holes are completely within recesses in the concrete surface.

(3) Unless otherwise stated in the Contract or permitted by the Engineer, chamfers shall be provided for all external angles of 90° or less in concrete surfaces with Class F2, F3, F4 and F5 finishes.

(4) Formwork for curved concrete surfaces with Class F2, F3, F4 and F5 finishes shall not be made up of a series of flats unless permitted by the Engineer.

Construction of formwork for Class F4 and F5 finishes

14.31 (1) Each type of formwork for Class F4 and F5 finishes shall be obtained from one source and different types of formwork shall not be mixed unless permitted by the Engineer. Damaged formwork shall not be used unless permitted by the Engineer. Parts of steel formwork which will be in contact with concrete shall be free from rust.

(2) For concrete surfaces with Class F4 and F5 finishes, joints between formwork panels shall be sealed with foamed rubber strips. The foamed rubber strips shall be sufficiently compressible to form a grout-tight joint. The width of the resulting gap between the panels shall not be greater than 1 mm and the sealing strips shall not protrude proud of the surface of the formwork panels. Alternatively, subject to the approval of the Engineer, joints between formwork panels may be sealed with an approved filler provided the butting edges of the panels are smooth and the resulting gap between the panels is not wider than 1 mm. Joints between formwork panels shall not be sealed by tape fixed to the formwork faces.

(3) Formwork for Class F4 and F5 finishes shall be protected from spillages, rust marks and stains.

Built-in components

14.32 Built-in components, void formers and box-outs shall be fixed in position before concreting. Unless permitted by the Engineer, void formers and box-outs shall not be used instead of built-in components. Polystyrene shall not be used for void formers and box-outs unless permitted by the Engineer.

APPLICATION OF RELEASE AGENTS

Application of release agents

14.33 (1) A release agent shall be used on all formwork other than permanent formwork and formwork on which a surface retarder is used to produce a Class T1 finish. The release agent shall be applied by the method and at the rate of application recommended by the manufacturer or as demonstrated to be satisfactory by use in the trial panel.

(2) Formwork faces shall be cleaned before release agents are applied. Concrete, reinforcement and built-in components shall not be contaminated by release agents.

(3) Each type of release agent used on formwork for Class F4 and F5 finishes shall be obtained from one manufacturer and different types of release agent shall not be used on formwork for the same element.

(4) Release agents shall be applied to formwork for Class F4 and F5 finishes after the formwork has been erected and before the reinforcement is fixed or, if this is not practicable, immediately before the formwork is erected. The release agent covering shall be complete and uniform.

INSPECTION OF FORMWORK AND REINFORCEMENT

Inspection of formwork and reinforcement 14.34 (1) The Contractor shall allow the Engineer to inspect the completed formwork and reinforcement, including trial panels, before carrying out any work, including fixing reinforcement adjacent to formwork and erecting formwork adjacent to reinforcement, which will make access to the formwork faces or reinforcement difficult. The Contractor shall inform the Engineer 24 hours, or such shorter period agreed by the Engineer, before carrying out such work.

(2) The Contractor shall allow the Engineer to inspect formwork for Class F4 and F5 finishes before it is erected and shall inform the Engineer 24 hours, or such shorter period agreed by the Engineer, before erecting the formwork.

REMOVAL OF FALSEWORK AND FORMWORK

Times for removal of falsework and formwork 14.35 (1) Except as stated in Clause 14.35(3), falsework and formwork shall not be loosened or removed before the minimum times stated in Table 14.6 have elapsed. The times stated are for a minimum ambient temperature of 15°C, for elements without superimposed loads and for concrete containing OPC, PPFAC or both OPC and PFA not exceeding the OPC replacement level as specified in Clause 16.14. If other conditions apply, particulars of proposed changes to the minimum times shall be submitted to the Engineer for approval.

(2) For the purpose of determining the minimum times for loosening or removing falsework and formwork, copings at the top of columns in water retaining structures shall be classified as slabs and roof slabs in water retaining structures shall be classified as beams.

(3) Falsework and formwork supporting concrete in flexure may be loosened or removed when the strength of the concrete in that element is 10 MPa or twice the stress to which it will be subjected, whichever is greater, provided that deflection which in the opinion of the Engineer is unacceptable will not result and that superimposed loads will not be applied. The strength of the concrete shall be determined from tests on test cubes which have been made with concrete from the same pour and which have been cured by the same method and under similar conditions as the concrete in the element.

Table 14.6: Minimum times for loosening or removing falsework and formwork

Type of falsework or formwork	Class F1, F2, F3 and F4 finishes		Class F5 finish
	Concrete without PFA	Concrete with PFA	Concrete with or without PFA
Vertical (non-profiled) (profiled)	12 hours 7 days	15 hours 7 days	48 hours 7 days
Inclined to top surfaces	12 hours	15 hours	48 hours
Soffits of slabs (props left in)	4 days	4 days	10 days
Soffits of beams (props left in)	7 days	7 days	14 days
Props to slabs	10 days	10 days	10 days
Props to beams	14 days	14 days	14 days

Removal of falsework and formwork 14.36 (1) Formwork shall be removed without hammering or levering to the concrete and in such a manner that there is no shock, disturbance, damage or loading to the concrete. Side formwork shall be removed without disturbing soffit formwork and soffit formwork shall be removed without disturbing props except as provided for in Clause 14.36(2).

(2) Individual props may be removed to allow the removal of soffit formwork provided that the formwork has been designed accordingly and that each prop is replaced as soon as the formwork has been removed.

(3) Falsework and formwork for Class F5 finishes shall be loosened and removed in a continuous operation and in accordance with a consistent programme agreed by the Engineer. All formwork shall be loosened before individual panels are removed and all formwork shall be removed within the programmed period. Individual panels or make-up pieces shall not be left in position.

(4) After removal, formwork which is intended for re-use shall be cleaned and stored as stated in Clause 14.26.

UNFORMED FINISHES

Unformed finishes 14.37 (1) Unformed finishes shall be produced by the methods stated in Table 14.2.

(2) Brushing to produce a Class U4 finish shall be carried out in straight lines in a direction agreed by the Engineer; brushing shall be carried out when the concrete has hardened sufficiently for the float marks to be removed and for the ridges to be formed without displacing the aggregate.

(3) Floating and trowelling shall not be carried out until the concrete has hardened sufficiently to allow the specified finish to be produced with the minimum amount of floating and trowelling such that excess laitance is not produced.

TREATED FINISHES

Treated finishes 14.38 (1) Treated finishes shall be produced by constructing a concrete surface with a Class F3 or U3 finish as appropriate and applying the treatment to the surface by the methods stated in Table 14.3.

(2) The treatment shall be applied in a continuous operation in accordance with a consistent programme agreed by the Engineer.

Class T1 finish 14.39 (1) Washing and brushing to produce a Class T1 finish shall not be carried out until the concrete has hardened sufficiently for the cement matrix to be removed without disturbing the coarse aggregate. After washing and brushing have been completed and the concrete surface has hardened, the surface shall be cleaned.

(2) The cement matrix shall not be removed or the aggregate exposed by mechanical methods unless permitted by the Engineer.

(3) Class T1 finishes may be produced by using a surface retarder applied to the formwork or to the concrete surface. The surface retarder shall be applied by the method and at the rate of application recommended by the manufacturer, or as demonstrated to be satisfactory by use on the trial panel.

(4) Plywood to which a surface retarder is to be applied shall be sealed with barrier paint, polyurethane varnish or other impermeable material agreed by the Engineer. The formwork shall be removed in small sections and the coarse aggregate exposed by washing and brushing the concrete surface.

(5) Unless permitted by the Engineer, formwork to which a surface retarder has been applied shall not be re-used unless a surface retarder is to be used again on the formwork. Formwork to which a surface retarder has been applied and which is to be re-used shall be cleaned before the retarder is applied.

Class T2 and T3 finishes 14.40 Point tooling to produce Class T2 finishes and bush hammering to produce Class T3 finishes shall be carried out evenly in small areas and not in distinct lines. Tooling and hammering shall not start until at least 7 days after concreting.

Class T4 finish 14.41 Hammering or chiselling to produce a Class T4 finish shall be applied from only one direction, and only either hammering or chiselling shall be applied, on any one face. Hammering and chiselling shall not start until at least 14 days after concreting.

Class T5 and T6 finishes 14.42 Blasting to produce Class T5 and T6 finishes shall not be carried out until the concrete has hardened sufficiently for the cement matrix to be removed without disturbing the coarse aggregate. Adjacent surfaces shall be protected from blasting and dust shall be controlled by screens and by water-spraying.

COMPLIANCE OF FINISHES

Inspection of finishes 14.43 (1) Before any subsequent work is carried out on a concrete surface, the surface shall be inspected by the Engineer to determine if the specified finish has been produced. Formed finishes shall be inspected as soon as the formwork has been removed.

(2) Blowholes or holes left by formwork ties and components shall not be filled and spatterdash or other coverings shall not be applied before the inspection; any such filling or covering carried out before the inspection may be rejected.

Compliance of finishes 14.44 (1) Concrete surfaces shall have the characteristics stated in Tables 14.1 and 14.2 for the different Classes of formed and unformed finish before any subsequent work is carried out on the concrete surface and shall have the characteristics stated in Table 14.3 for the different Classes of treated finish.

(2) The Engineer shall determine if the specified finish has been produced and may use the trial panels as a means of comparison.

(3) Abrupt irregularities shall be measured by direct measurement. Gradual irregularities shall be measured using a 2 m long straight edge on surfaces intended to be flat and by a method agreed by the Engineer on other surfaces.

WORK ON CONCRETE SURFACES

Remedial and repair work on concrete surfaces 14.45 Remedial or repair work shall not be carried out on concrete surfaces unless permitted by the Engineer; any such work carried out without permission may be rejected.

Filling blowholes and formwork tie holes

14.46 (1) Blowholes exceeding 3 mm in size in water retaining structures and water tight structures, and blowholes exceeding 10 mm in size in other structures shall be filled with cement mortar. The size of blowholes shall be the maximum dimension measured across the hole on the concrete surface. If the number and size of blowholes in concrete surfaces with Class F3, F4 and F5 finishes is in the opinion of the Engineer greater than in the trial panel the blowholes shall be filled, unless in the opinion of the Engineer filling is not required.

(2) Holes left by formwork ties and components shall be cleaned and filled by ramming cement mortar into the holes in layers. Holes in concrete surfaces with a Class F5 finish shall be filled to a level slightly below the concrete surface; the holes shall not be overfilled and rubbed down.

(3) Filling of blowholes and holes left by formwork ties and components shall be carried out as soon as practicable after the Engineer has inspected the finish and with the minimum interruption to curing.

Spatterdash

14.47 (1) Spatterdash shall consist of cement and coarse sand or granite fines in the proportions 1:2 by volume mixed with the minimum amount of water necessary to achieve the consistency of a thick slurry. Spatterdash shall be thrown with a hand trowel onto the surface to a thickness not exceeding 6 mm and shall cover at least 60% of the area which is to be plastered or rendered. Spatterdash shall be wetted one hour after application and shall be allowed to cure and harden before under coats are applied.

(2) Spatterdash shall be applied as soon as practicable after the Engineer has inspected the finish and after the concrete surface has been cleaned and wetted.

PROTECTION OF FINISHES

Protection of finishes

14.48 (1) Materials, Constructional Plant or other vehicles shall not use or be placed on or against concrete surfaces unless permitted by the Engineer.

(2) Concrete surfaces with Class F4, F5, U5 and T finishes shall be protected from running water, spillages, rust-marks and stains by covering the surface with polyethylene sheeting or timber or by other methods agreed by the Engineer. Protection from rust-marks caused by reinforcement bars shall be by polyethylene sleeves tied to the bars or by coating the bars with cement slurry; the bars shall not be coated with oil or grease.

(3) Concrete surfaces with Class F4, F5, U5 and T finishes shall be protected from damage by securing timber battens to the surface, by erecting barriers or fences or by other methods agreed by the Engineer.

(4) Concrete surfaces with a Class F5 finish shall be protected from exposure to extreme variations in weather conditions for at least 14 days after the formwork has been removed.

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 15

STEEL REINFORCEMENT

SECTION 15

STEEL REINFORCEMENT

GLOSSARY OF TERMS

Reinforcement connector 15.01 Reinforcement connector is a coupler or sleeve designed to transmit the force between two bars in tension or compression.

Bar reinforcement 15.02 Bar reinforcement is hot rolled steel bar reinforcement.

MATERIALS

Bar reinforcement and fabric reinforcement 15.03 Bar reinforcement and fabric reinforcement shall comply with the following:

Hot rolled steel bars	: CS 2
Cold reduced steel wire	: BS 4482
Steel fabric	: BS 4483.

Epoxy coatings to reinforcement 15.04 (1) Epoxy coatings to reinforcement and patching material for epoxy coatings shall comply with BS 7295 : Parts 1 & 2 except as stated in Clauses 15.04(2), 15.21, 15.31, 15.32 and 15.36. The coatings shall be applied by the electrostatic spray method in accordance with BS 7295 : Part 1 at a factory approved by the Engineer.

(2) The film thickness of the coating after curing shall be at least 0.15 mm and shall not exceed 0.28 mm over the complete periphery including deformations and ribs. The bond classification of coated bars determined in bond performance tests shall not be less than that of uncoated bars.

Galvanizing to reinforcement 15.05 (1) Galvanizing to reinforcement shall comply with BS 729. Galvanized reinforcement shall be chromate passivated as part of the galvanizing process by quenching the bars immediately after galvanizing in a solution containing at least 0.2% sodium dichromate in water. The galvanizing shall be applied after cutting and bending of the reinforcement.

(2) Metallic zinc-rich priming paint for repairs to galvanized reinforcement shall comply with BS 4652.

Reinforcement connectors

15.06 (1) Reinforcement connectors shall be a proprietary type approved by the Engineer.

(2) Reinforcement connectors for tension joints shall be a cold swaged or threaded type. The connectors shall be capable of developing the full tensile strength of the parent bar and shall comprise high tensile steel studs and seamless steel tubes fitted with protective plastic caps.

(3) Reinforcement connectors for compression joints shall be a wedge locking or bolted sleeve type.

Cover spacers

15.07 (1) Cover spacers for reinforcement shall be concrete blocks or a proprietary plastic or concrete type. Proprietary plastic and concrete cover spacers shall be a type approved by the Engineer.

(2) Cover spacers for Class F3, F4 and F5 finishes shall be a proprietary plastic or concrete type. Cover spacers for epoxy coated reinforcement and galvanized reinforcement shall be a proprietary plastic type.

(3) Cover spacers shall be as small as practicable consistent with their purpose and shall be designed to maintain the specified cover to reinforcement. Cover spacers shall be capable of supporting the weight of reinforcement and construction loads without breaking, deforming or overturning.

(4) The strength and durability of concrete blocks and proprietary concrete cover spacers shall not be less than that of the surrounding concrete.

(5) Cover spacers for Class F3, F4 and F5 finishes shall be of a colour similar to that of the surrounding concrete and shall not cause indentations in the formwork.

Chairs, supports and spacers

15.08 Chairs, supports and spacers other than cover spacers for reinforcement shall be steel. The steel shall be coated with nylon, epoxy, plastic or other dielectric material for epoxy coated reinforcement and shall be galvanized for galvanized reinforcement.

Tying wire

15.09 Tying wire for reinforcement adjacent to and above Class F4 and F5 finishes shall be 1.2 mm diameter stainless steel wire. Tying wire for epoxy coated reinforcement shall be 1.6 mm diameter soft annealed steel wire coated with nylon, epoxy, plastic or other dielectric material. Tying wire for galvanized reinforcement shall be 1.6 mm diameter galvanized soft annealed steel wire. Tying wire for other reinforcement shall be 1.6 mm diameter soft annealed steel wire.

Tying devices and clips

15.10 Tying devices and clips for reinforcement shall be a proprietary steel type approved by the Engineer. Tying devices and clips for reinforcement adjacent to and above Class F4 and F5 finishes shall be stainless steel. Tying devices and clips for epoxy coated reinforcement shall be coated with nylon, epoxy, plastic or other dielectric material. Tying devices and clips for galvanized reinforcement shall be galvanized.

SUBMISSIONS

Particulars of bar reinforcement and fabric reinforcement

15.11 (1) The following particulars of the proposed bar reinforcement and fabric reinforcement shall be submitted to the Engineer:

(a) for Class 1 bar reinforcement, a certificate from the quality assured stockist in accordance with CS 2 Cl. 4.1.3 and a copy of the manufacturer's third party certificate

(b) for Class 2 bar reinforcement, a certificate from the quality assured stockist in accordance with CS 2 Cl. 4.1.4 and a copy of the manufacturer's third party certificate

(c) for Class 3 bar reinforcement, a certificate from the supplier in accordance with CS 2 Cl. 4.2

(d) Upon delivery of bar reinforcement the contractor shall submit a test report containing the details specified in CS 2 Cl. 3.3.3 and Cl. 3.3.5.

(e) for fabric reinforcement, a certificate from the manufacturer showing the manufacturer's name, the date and place of manufacture and showing that the reinforcement complies with the requirements stated in the Contract and including details of:
- bond classification
- cast analysis
- carbon equivalent value
- results of tensile, bend and rebend tests, including the effective cross-sectional area for tensile tests
- results of bond performance tests
- results of weld tests

(2) The particulars shall be submitted to the Engineer for information for each batch of bar reinforcement and fabric reinforcement delivered to the Site and at least 14 days before fixing of the reinforcement starts.

Particulars of epoxy coatings to reinforcement

15.12 (1) The following particulars of the proposed epoxy coatings to reinforcement shall be submitted to the Engineer:

(a) name and location of the coating factory,

(b) mill sheets of the steel reinforcement,

(c) date and place of the coating application, and

(d) certificate of the coating materials in compliance with BS 7295 : Part 2, including:

- corrosion resistance
- chemical resistance
- cathodic disbonding of coating
- adhesion of coating
- abrasion resistance
- impact strength
- hardness

The above tests shall be carried out once every 5 years or when there are changes in the composition of the coating materials whichever is the earlier.

(2) The particulars, including certificates and test results in Clause 15.12(1), shall be submitted to the Engineer at least 14 days before the first delivery of epoxy coated reinforcement to the Site. Certificates shall be submitted for each batch of epoxy coated reinforcement delivered to the Site and at least 14 days before fixing of the reinforcement starts.

Particulars of galvanized coatings to reinforcement

15.13 (1) The following particulars of the proposed galvanized coatings to reinforcement shall be submitted to the Engineer:

(a) name and location of the coating factory, and

(b) a certificate from the manufacturer showing the date and place of application of the coating and showing that the galvanized coatings comply with the requirements stated in the Contract and including results of tests for:

- weight of coating
- uniformity of coating.

(2) The particulars shall be submitted to the Engineer for each batch of galvanized reinforcement delivered to the Site and at least 14 days before fixing of the reinforcement starts.

Particulars of reinforcement connectors

15.14 Particulars of the proposed materials and methods of installation for reinforcement connectors, including the manufacturer's literature, shall be submitted to the Engineer at least 28 days before fixing of reinforcement connectors starts.

Bending schedules

15.15 Bending schedules complying with BS 4466, Clause 4 shall be prepared by the Contractor and submitted to the Engineer before bending of reinforcement starts.

Samples of materials

15.16 Samples of the following proposed materials shall be submitted to the Engineer at the same time as particulars of the material are submitted:

(a) bar and fabric reinforcement,

(b) epoxy coated bar and fabric reinforcement,

(c) galvanized bar and fabric reinforcement,

(d) reinforcement connectors for tension joints and compression joints,

(e) cover spacers, and

(f) tying wire, tying devices and clips.

HANDLING AND STORAGE OF MATERIALS

Handling of reinforcement

15.17 (1) Reinforcement shall not be subjected to rough handling, shock loading or dropping from a height.

(2) Nylon, rope or padded slings shall be used for lifting epoxy coated reinforcement and galvanized reinforcement; bundles shall be lifted with a strongback or with multiple supports to prevent abrasion.

Storage of reinforcement

15.18 (1) Reinforcement shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to the reinforcement or in contamination of the reinforcement. Fabric reinforcement shall be stored horizontally.

(2) Different types and sizes of reinforcement shall be stored separately.

(3) Reinforcement shall not be stored on or adjacent to concrete surfaces which form part of the permanent work.

(4) Epoxy coated reinforcement and galvanized reinforcement shall be stored on wooden or padded cribbing.

CUTTING AND BENDING REINFORCEMENT

Cutting and bending reinforcement

15.19 (1) Reinforcement shall be cut and bent in accordance with BS 4466 to the specified shapes and dimensions and shall be bent at temperatures of at least 5°C and not exceeding 100°C.

(2) Epoxy coated reinforcement shall be bent cold. Bar cutting and bar bending equipment for epoxy coated reinforcement shall have padded supports and contact areas shall be fitted with nylon or plastic mandrels.

(3) Grade 460/425 reinforcement shall not be rebent or straightened after bending. Grade 250 reinforcement which projects from the hardened concrete may be bent aside and rebent provided that the internal radius of the bend is at least twice the diameter of the bar and that bending is not carried out by levering against the concrete or by other methods which in the opinion of the Engineer are likely to damage the concrete.

(4) The ends of bars to be used with reinforcement connectors for compression joints shall be sawn square with all burrs removed.

SURFACE CONDITION OF REINFORCEMENT

Surface condition of reinforcement

15.20 (1) Reinforcement shall be clean at the time of fixing and shall be free from loose mill scale, loose rust or any substance which in the opinion of the Engineer is likely to reduce the bond or affect the reinforcement or concrete chemically; the reinforcement shall be maintained in this condition until concrete is placed around it.

(2) If the surface condition of the reinforcement deteriorates such that it does not comply with the requirements stated in Clause 15.20(1), the reinforcement shall be cleaned or dealt with by other methods agreed by the Engineer.

Repairs to epoxy coatings and galvanized coatings

15.21 (1) If the coating to epoxy coated reinforcement is delaminated or split at any point or if the coating to epoxy coated reinforcement or galvanized reinforcement is damaged:

(a) at any point by an amount exceeding 25 mm^2 in area or 50 mm in length, or

(b) at more than three points in a 1 m length by amounts each even not exceeding 25 mm^2 in area or 50 mm in length,

that part of the reinforcement shall not be used in the permanent work. If the coating to epoxy coated reinforcement or galvanized reinforcement is damaged at more than six points in the cut and bent length of a bar by amounts each even not exceeding 25 mm^2 in area or 50 mm in length, that length of bar shall not be used in the permanent work.

(2) All damaged areas not exceeding 25 mm^2 in area or 50 mm in length and cut ends of epoxy coated reinforcement shall be repaired using patching material applied in accordance with the manufacturer's recommendations.

(3) Damaged areas not exceeding 25 mm^2 in area or 50 mm in length and cut ends of galvanized reinforcement shall be repaired by applying two coats of metallic zinc-rich priming paint. Sufficient paint shall be applied to provide a zinc coating of at least the same thickness as the galvanized coating.

(4) Repairs to epoxy coatings and galvanized coatings shall be carried out within 8 hours of cutting or damage. Traces of rust shall be removed from the surface of the reinforcement before the repair is carried out.

FIXING REINFORCEMENT

Fixing reinforcement

15.22 (1) Bar reinforcement, fabric reinforcement and reinforcement connectors for tension joints from each batch shall not be fixed until testing of the batch has been completed.

(2) Reinforcement shall be fixed rigidly in position and secured against displacement.

(3) A sufficient number of intersecting and lapping bars shall be tied using tying wire, tying devices or clips to prevent movement of the reinforcement. The ends of tying wire, tying devices and clips shall not encroach into the cover to reinforcement.

(4) Laps and joints in reinforcement shall be made only at the specified positions and by the specified method.

(5) Sufficient numbers of cover spacers, chairs, supports and spacers other than cover spacers shall be provided to maintain the reinforcement in the correct location and to maintain the specified cover at all positions. Cover spacers, chairs, supports and spacers other than cover spacers shall be placed at a maximum spacing of 1.5 m. Chairs, supports and spacers other than cover spacers shall be positioned adjacent to or above cover spacers and shall have at least the same cover as that specified for the reinforcement.

(6) Prefabricated reinforcement cages shall be adequately supported and braced before lifting.

(7) Reinforcement which is free-standing shall be secured in position and braced to prevent movement due to wind and other loads.

Fixing reinforcement connectors 15.23 Reinforcement connectors shall be fixed in accordance with the manufacturer's recommendations and using equipment recommended by the manufacturer.

Welding of reinforcement 15.24 Reinforcement shall not be welded unless approved by the Engineer.

Exposed reinforcement 15.25 Reinforcement which is to be left exposed shall be protected by coating with cement slurry or by other methods agreed by the Engineer.

Access over reinforcement 15.26 Reinforcement shall not be contaminated or displaced as a result of access over the reinforcement; access shall be obtained by using planks and ladders or by other methods agreed by the Engineer.

TOLERANCES

Tolerances: reinforcement 15.27 (1) Tolerances on cutting and bending reinforcement shall comply with BS 4466, Table 2.

(2) The cover to reinforcement shall be within 5 mm of the specified cover.

INSPECTION OF REINFORCEMENT

Inspection of reinforcement 15.28 The Contractor shall allow the Engineer to inspect the completed reinforcement before carrying out any work, including erecting formwork adjacent to reinforcement, which will make access to the reinforcement difficult. The Contractor shall inform the Engineer 24 hours, or such shorter period agreed by the Engineer, before carrying out such work.

TESTING: REINFORCEMENT

Batch: reinforcement 15.29 (1) For the purpose of testing, the steel bar reinforcement arriving on site is to be subdivided into batches. Each batch shall consist of reinforcement of the same steel grade, the same nominal diameter, same cast number, batch number or lot number.

(2) A batch of fabric reinforcement or reinforcement connectors for tension joints is any quantity of fabric reinforcement or reinforcement connectors for tension joints of the same type, size and grade, manufactured by the same mill, covered by the same mill and testing certificates and delivered to the Site at any one time. In addition, for epoxy coated reinforcement and galvanized reinforcement, the coatings shall have been applied at the same coating factory and shall be covered by the same test certificates.

Samples: reinforcement 15.30 (1) Samples of bar reinforcement, fabric reinforcement and reinforcement connectors for tension joints, except for epoxy coated reinforcement, shall be provided from each batch of the material delivered to the Site and at least 14 days before fixing of the reinforcement starts. The number of samples to be provided from each batch shall be as stated in Table 5.1. For epoxy coated reinforcement, samples shall be provided at least 20 working days before fixing of the reinforcement starts.

(2) The number of specimens in each sample shall be as follows:

(a)	bar reinforcement (without epoxy coating or galvanized coating)	: In accordance with CS 2 Table 9
(b)	epoxy coated bar reinforcement and galvanized bar reinforcement	: 2 additional specimen to those specified in CS 2 Table 9 for bar reinforcement
(c)	fabric reinforcement (without epoxy coating or galvanized coating)	: 3
(d)	epoxy coated fabric reinforcement and galvanized fabric reinforcement	: 4
(e)	reinforcement connectors for tension joints	: 3

(3) Each specimen of bar reinforcement shall be 1 m long. Each specimen of fabric reinforcement shall be 1.2 m long by 1.2 m wide and shall contain at least three wires in each direction. Each specimen of reinforcement connectors shall consist of one reinforcement connector joined to two lengths of bar each 500 mm long; the bars shall be the same type, size and grade as the bars to which the reinforcement connector will be fixed in the permanent work.

(4) Each specimen of bar reinforcement and fabric reinforcement shall be taken from different bars or sheets in the batch. The ends of specimens shall be cut square before delivery to the laboratory.

(5) For epoxy coated bar reinforcement, two additional specimens shall be selected by the Engineer from each batch of reinforcement for epoxy coating tests on thickness, adhesion and continuity in addition to the requirements of tensile tests, bend tests and rebend tests. Each specimen shall be a 2 m length piece cut at least 1 m from the ends of a 12 m length bar. Specimens shall be selected from different bundles of the reinforcement batch.

Table 15.1: Rate of sampling of reinforcement

Description	Size of batch	No. of samples per batch
Bar reinforcement	All sizes	1
Fabric reinforcement	0 - 50 tonnes	1
	exceeding 50 tonnes	1 for each 50 tonnes or part thereof
Reinforcement connectors for tension joints	less than 100 No.	1
	100 - 500 No.	2
	exceeding 500 No.	3

Testing: reinforcement 15.31 (1) Each sample of bar reinforcement and fabric reinforcement shall be tested to determine the yield stress, elongation, tensile strength, bending and rebending properties and unit mass. Each sample of fabric reinforcement shall also be tested to determine the weld shear strength. Each sample of epoxy coated reinforcement shall also be tested to determine the thickness, adhesion and continuity of the coating. Each sample of galvanized reinforcement shall also be tested to determine the weight and uniformity of coating.

(2) Each sample of reinforcement connectors for tension joints shall be tested to determine the tensile strength and the permanent elongation in accordance with Clause 15.33.

(3) The number of tests on each sample shall be as stated in Table 15.2.

(4) The method of testing shall be in accordance with the following:

Hot rolled steel bars	: CS 2
Cold reduced steel wire	: BS 4482
Steel fabric	: BS 4483
Galvanized coating	: BS 729

(5) Thickness, adhesion and continuity tests on epoxy coatings shall be performed on each additional test specimen as selected in accordance with Clause 15.30(5). The thickness test shall be in accordance with Method No. 6 of BS 3900: Part C5. For thickness test, 15 pairs of readings shall be taken along two opposite sides of each specimen. The adhesion and continuity tests shall be in accordance with BS 7295: Part 1. Bend tests for adhesion shall be performed at a uniform rate within 15 seconds.

(6) Tests shall be carried out on specimens having a temperature of between 5°C and 30°C.

Compliance criteria: epoxy coatings to reinforcement

15.32 The results of tests for thickness, adhesion and continuity of epoxy coatings to reinforcement shall comply with the following requirements:

(a) All coating thickness measured from the two specimens selected in accordance with Clause 15.30(5) shall not be less than 0.13 mm.

(b) Cracking or debonding of the coating shall not be visible to the unaided eye on any part of the bent bar.

(c) The continuity of the coating shall comply with BS 7295 : Part 1, Clause 4.2.

Compliance criteria: reinforcement connectors for tension joints

15.33 The results of tensile tests on specimens of reinforcement connectors for tension joints shall comply with the following requirements:

(a) The tensile strength shall not be less than the specified requirements for the parent bar.

(b) When a test is made of a representative gauge length assembly comprising reinforcement of the size, grade and profile to be used and a reinforcement connector for tension joints of the precise type to be used, the permanent elongation after loading to 0.6 times of the specified characteristic strength and unloading shall not exceed 0.1 mm. The gauge length shall span over the reinforcement connector.

Table 15.2: Number of tests on each sample of reinforcement

Description	Type and number of tests							
	Tensile	Bend	Rebend	Unit Mass	Weld Shear Stress	Thickness, Adhesion and Continuity	Weight and Uniformity of Galvanized Coating	Pitch, Dimension
Bar reinforcement	No. of tensile, bend and rebend tests in accordance with CS2 Table 9 and one unit mass test accompanied with each tensile test				-	-	-	-
Steel fabric - fabric sheet - longitudinal wire - transverse wire	- 3 3	- - -	- 1 1	3 - -	1 - -	- - -	- - -	- 1 1
Epoxy coating	-	-	-	-	-	2	-	-
Galvanized coating	-	-	-	-	-	-	2	-
Reinforcement connectors for tension joints	3	-	-	-	-	-	-	-

Non-compliance: characteristic strength

15.34 (1) A batch of bar reinforcement shall be considered as not complying with the specified requirements for characteristic strength if the tensile tests results cannot meet the requirements stated in CS 2 Cl. 5.1.2(a).

(2) A batch of fabric reinforcement shall be considered as not complying with the specified requirements for characteristic strength if the yield stress in any tensile test carried out on any sample taken from the batch is less than 93% of the specified characteristic strength.

(3) If the yield stress of fabric reinforcement in any tensile test is less than the specified characteristic strength but equal to or greater than 93% of the specified characteristic strength, additional samples shall be provided from the same batch and additional tests for yield stress shall be carried out. The number of additional samples shall be as stated in Table 15.1. The number of fabric reinforcement specimens in each additional sample shall be seven. The number of tests on the longitudinal wires and on the transverse wires of each additional sample of fabric reinforcement shall be seven. The batch shall be considered as not complying with the specified requirements for characteristic strength if the yield stress in any additional test is less than 93% of the specified characteristic strength.

Non-compliance: elongation, tensile strength, bending, rebending, unit mass, weld shear strength

15.35 (1) If the result of any test for elongation, tensile strength, bending, rebending, unit mass or weld shear strength of bar reinforcement, fabric reinforcement or reinforcement connectors for tension joints does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be as stated in Table 15.1.

(2) The number of specimens in each additional sample shall be as follows:

(a)	bar reinforcement (test to determine the elongation, tensile strength or mass)	: 2 additional test specimens for each test failed
(b)	bar reinforcement (test to determine the bending or rebending properties)	: 2 additional test specimens for each test failed
(c)	fabric reinforcement	: 6
(d)	reinforcement connectors for tension joints	: 6

(3) The number of tests on each additional sample shall be as follows:

(a)	tensile test	
	- bar reinforcement	: 1 for each specimen
	- reinforcement connectors for tension joints	: 6
	- fabric reinforcement	
	- longitudinal wires	: 6
	- transverse wires	: 6
(b)	bend test	: 2
(c)	rebend test	: 2
(d)	unit mass	: 1 for each specimen
(e)	weld shear strength	: 2.

(4) The batch shall be considered as not complying with the specified requirements for the property if the result of any additional test does not comply with the specified requirements for the property.

Non-compliance: thickness, adhesion and continuity of epoxy coatings

15.36 In testing the two specimens selected in accordance with Clause 15.30(5), if one test specimen fails to meet the coating thickness, coating adhesion or coating continuity requirements, retests of specimens of the same batch are permitted, and two further specimens from the same batch shall be subjected to the test or tests in which the original specimen failed. If both additional specimens pass the retest, the batch from which they were taken shall be deemed to comply with the specification. If either or both of them fails in the retests, the batch shall be deemed not to comply with the specification, and this batch shall be rejected and removed from Site.

Non-compliance: weight and uniformity of galvanized coatings

15.37 (1) If the result of any test for weight or uniformity of galvanized coatings to reinforcement does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be as stated in Table 15.1.

(2) The number of specimens in each additional sample shall be as follows:

(a) galvanized bar reinforcement : 4

(b) galvanized fabric reinforcement : 2.

(3) The number of tests on each additional sample shall be four.

(4) The batch shall be considered as not complying with the specified requirements for the property if the result of any additional test does not comply with the specified requirements for the property.

Non-compliance: permanent elongation of reinforcement connectors

15.38 (1) If the result of any test for permanent elongation of reinforcement connectors for tension joints does not comply with the specified requirements as stated in Clause 15.33(b), additional samples shall be provided from the same batch and additional tests for permanent elongation as stated in Clause 15.33(b) shall be carried out. The number of additional samples shall be as stated in Table 15.1.

(2) The number of specimens in each additional sample shall be six.

(3) The number of tests on each additional sample shall be six.

(4) The batch shall be considered as not complying with the specified requirements for permanent elongation if the result of any additional test does not comply with the specified requirements as stated in Clause 15.33(b).

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 16

CONCRETE AND JOINTS IN CONCRETE

SECTION 16

CONCRETE AND JOINTS IN CONCRETE

PART 1: CONCRETE WORKS

GENERAL

Sprayed concrete 16.01 Sprayed concrete shall comply with Section 7 except as stated in this Section.

Designation of concrete mixes 16.02 (1) Designed mix concrete shall be designated by the grade strength in MPa followed by the nominal maximum aggregate size in mm and the suffix D.

(2) Standard mix concrete shall be designated by the grade strength in MPa followed by the nominal maximum aggregate size in mm and the suffix S.

(3) Designed mix concrete or standard mix concrete of the same grade strength but with different constituents, workabilities or other properties shall be designated as such by the addition of a suitable description. If the grade of concrete is designated by one number only, the number shall be the grade strength in MPa.

GLOSSARY OF TERMS

Cementitious content 16.03 Cementitious content is the mass of cement per cubic metre of compacted concrete or, if cement and PFA are used as separate constituents, the combined mass of cement and PFA per cubic metre of compacted concrete.

Grade 16.04 Grade is a term used to identify the different concrete mixes in terms of grade strength or in terms of grade strength and nominal maximum aggregate size.

Grade strength 16.05 Grade strength is the compressive strength of concrete stated in the Contract. For designed mix concrete, compliance with the grade strength shall be ascertained in accordance with Clause 16.61.

MATERIALS

Cement 16.06 (1) Cement shall comply with the following:

Ordinary and rapid hardening Portland cement	: BS 12
Sulphate resisting Portland cement	: BS 4027

Portland pulverised-fuel ash cement	: BS 6588.

(2) The PFA content of PPFAC shall be 25% ± 3% by mass of the PPFAC.

PFA 16.07 PFA shall comply with BS 3892: Part 1 except that the criterion for maximum water requirement shall not apply.

Aggregates 16.08 (1) Aggregates shall be obtained from a source approved by the Engineer.

(2) Fine aggregate shall be clean, hard, durable crushed rock, or natural sand, complying with BS 882, except that the NOTE in Table 5 of BS 882 shall not apply.

(3) Coarse aggregate shall be clean, hard, durable crushed rock complying with BS 882. The ten percent fines values shall be at least 100 kN. The water absorption shall not exceed 0.8%. The flakiness index shall not exceed 35%.

Water 16.09

Admixtures 16.10 (1) Admixtures shall comply with the following:

Pigments for Portland cement and Portland cement products	: BS 1014
Accelerating admixtures, retarding admixtures and water-reducing admixtures	: BS 5075: Part 1
Superplasticising admixtures	: BS 5075: Part 3.

(2) The chloride ion content of admixtures for concrete containing embedded metal or for concrete made with SRPC shall not exceed 2% by mass of the admixture or 0.03% by mass of the cementitious content, whichever is less.

Curing compound

16.11 (1) Curing compound shall be a proprietary type approved by the Engineer and shall have an efficiency index of at least 80%.

(2) Curing compound shall contain a fugitive dye. Curing compounds containing organic solvents shall not be used. The curing compound shall become stable and achieve the specified resistance to evaporation of water from the concrete surface within 60 minutes after application. Curing compound shall not react chemically with the concrete to be cured and shall not crack, peel or disintegrate within one week after application. Curing compound shall degrade completely within three weeks after application.

(3) Curing compound for use on concrete surfaces against which potable or fresh water will be stored or conveyed shall be non-toxic and shall not impart a taste to the water.

CONCRETE

Concrete mix

16.12 (1) Concrete shall be a designed mix unless the Engineer permits the use of a standard mix. Designed mixes shall be designed by the Contractor.

(2) Unless otherwise permitted by the Engineer, the minimum design slump value for designed mix concrete for reinforced elements, after the addition of superplasticiser if used, shall be 75 mm. Should the Contractor wish to use designed mix concrete with a design slump value less than 75 mm in reinforced elements, the Engineer may require the Contractor to demonstrate that such concrete can be satisfactorily placed and compacted in trial sections simulating the appropriate sections of the Works.

(3) Cement, PFA, aggregates, water and admixtures for concrete shall comply with Clauses 16.06 to 16.10. All-in aggregate shall not be used.

(4) SRPC shall only be used if stated in the Contract. PFA shall not be used with SRPC.

(5) PFA shall not be used in addition to PPFAC.

Chloride content of concrete

16.13 The maximum total chloride content of concrete, expressed as a percentage relationship between the chloride ion and the cementitious content by mass in the concrete mix, shall be as stated in Table 16.1. If the concrete is of more than one of the types stated, then the lower value of maximum chloride content shall apply.

Table 16.1: Maximum total chloride content of concrete

Type of concrete	Maximum total chloride content (%)
Prestressed concrete. Steam-cured structural Concrete	0.1
Concrete with reinforcement or other embedded metal	0.35
Concrete made with SRPC	0.2

Cementitious content of designed mix concrete

16.14 (1) The minimum cementitious content of designed mix concrete of Grade 20 or above using 20 mm nominal maximum aggregate size shall be as stated in Table 16.2; the minimum cementitious contents shall be increased by 40 kg/m^3 for 10 mm nominal maximum aggregate size and decreased by 30 kg/m^3 for 40 mm nominal maximum aggregate size.

(2) Unless otherwise approved by the Engineer, the maximum cementitious content of designed mix concrete for water retaining structures and water tight structures shall be 400 kg/m^3 for concrete containing OPC and shall be 450 kg/m^3 for concrete containing either OPC and PFA or PPFAC. Unless otherwise approved by the Engineer, the maximum cementitious content of designed mix concrete other than for water retaining structures and water tight structures shall be 550 kg/m^3.

(3) The cementitious content of designed mix concrete may be varied during routine production at the discretion of the Contractor by an amount not exceeding 20 kg/m^3, provided that the total cementitious content is not less than the specified minimum value and does not exceed the specified maximum value.

(4) When PFA is incorporated in the concrete as a separate material, its proportion shall not exceed 35% of the total cementitious content for normal concrete. If other conditions apply, particulars of proposed changes to the proportion of PFA shall be submitted to the Engineer for approval.

Table 16.2: Minimum cementitious content of designed mix concrete of Grade 20 or greater with 20 mm nominal maximum aggregate size

Grade strength (MPa)	20	25	30	35	40	45	50
Minimum cementitious content (kg/m^3)	270	290	310	330	350	375	400

Standard mix concrete 16.15 Standard mix concrete shall comply with the following requirements:

(a) Cement shall be OPC or PPFAC.

(b) The total mass of dry aggregate to be used with 100 kg of OPC or with 110 kg of PPFAC shall be as stated in Table 16.3.

(c) The percentage by mass of fine aggregate to total aggregate shall be as stated in Table 16.4.

(d) Admixtures other than water-reducing admixtures shall not be used unless permitted by the Engineer.

Table 16.3: Mass of total aggregate for standard mix concrete

Grade strength (MPa)	Nominal maximum aggregate size (mm)	40	20	10
	Slump value (mm)	85-170	75-150	65-130
10	Mass of total aggregate (kg)	800	690	-
20		550	500	400
25		490	440	360
30		440	380	300

Table 16.4: Percentage by mass of fine aggregate to total aggregate for standard mix concrete

Grade strength (MPa)	Grading of fine aggregate (BS 882: Table 5)	Nominal maximum aggregate size (mm)	40	20	10
10	C, M or F	Percentage by mass of fine aggregate to total aggregate (%)	30 - 45	35 - 50	-
20, 25 or 30	C		30 - 40	35 - 45	45 - 55
	M		25 - 35	30 - 40	40 - 50
	F		25 - 30	25 - 35	35 - 45

No-fines concrete 16.16 No-fines concrete shall comply with the following requirements:

(a) Cement shall be OPC or PPFAC.

(b) The nominal maximum aggregate size shall be 20 mm; not more than 15% by mass shall be retained on a 20 mm BS test sieve and not more than 10% by mass shall pass a 10 mm BS test sieve.

(c) The aggregate:cement ratio by mass shall be at least 10 and shall not exceed 15.

(d) The cementitious content shall be such that each particle of aggregate is coated with cement paste but the compacted concrete has an open texture which permits the flow of water through the hardened concrete.

SUBMISSIONS

Particulars of materials for concrete 16.17 (1) The following particulars of the proposed cement, PFA and aggregates shall be submitted to the Engineer:

(a) a certificate not older than 6 months for each type of cement showing the manufacturer's name, the date and place of manufacture and showing that the cement complies with the requirements stated in the Contract and including results of tests for:
- chemical composition
- fineness
- compressive strength at 3, 7 and 28 days
- initial and final setting times
- soundness
- proportion by mass of PFA contained in PPFAC,

(b) a certificate not older than 6 months for PFA showing the source of the PFA and showing that the PFA complies with the requirements stated in the Contract and including results of tests for:
- chemical composition
- fineness
- moisture content, and

(c) a certificate not older than 6 months for each nominal maximum aggregate size showing the source of the aggregate and showing that the aggregate complies with the requirements stated in the Contract and including results of tests for:
- grading
- silt content
- chloride content
- flakiness index of coarse aggregate.
- ten percent fines value
- water absorption

(2) The following particulars of the proposed admixtures shall be submitted to the Engineer:

(a) manufacturers' literature,

(b) description of physical state, colour and composition,

(c) recommended storage conditions and shelf life,

(d) method of adding to the concrete mix,

(e) any known incompatibility with other admixtures or cement,

(f) recommended dosage,

(g) effects of under-dosage and over-dosage, and

(h) a certificate not older than 6 months for each type of admixture showing the manufacturer's name, the date and place of manufacture and showing that the admixture complies with the requirements stated in the Contract and including results of tests for:

- uniformity
- chloride content.

(3) The following particulars of the proposed curing compound shall be submitted to the Engineer:

(a) manufacturer's literature,

(b) description of physical state, colour and composition,

(c) recommended storage conditions and shelf life,

(d) method of application,

(e) recommended rate of application, and

(f) a certificate showing the manufacturer's name, the date and place of manufacture and showing that the curing compound complies with the requirements stated in the Contract and including results of tests for efficiency index.

(4) If recycled water is used for mixing concrete, results of the tests specified in Clause 16.51 and Table 16.7A shall be submitted to the Engineer.

COR No. 1/2003(March)

(5) The particulars, including certificates, shall be submitted to the Engineer at least 14 days before the first delivery of the material to the Site, and thereafter each time the source is changed. **COR No. 2001/03(March)**

Particulars of concrete mix

16.18 (1) The following particulars of each proposed designed concrete mix shall be submitted to the Engineer:

(a) quantity of each constituent per batch and per cubic metre of compacted concrete, with required tolerances on quantities of aggregates to allow for minor variations in grading, silt content etc. The maximum permitted variation in the quantity of fine aggregate shall be ± 20 kg of fine aggregate per 100 kg of cement.

(b) grading of coarse and fine aggregates,

(c) workability after the addition of superplasticisers, in terms of designed slump value or designed flow value,

COR No. 2/2005(June)

(d) method of placing concrete,

(e) method of controlling the temperature of the concrete, if required,

(f) test or trial mix data for designed mix concrete of the same grade and with similar constituents and properties, if available, and

(g) test data for designed mix concrete of the same or other grade produced in the plant or plants proposed to be used, if available.

(2) The particulars shall be submitted to the Engineer for information at least 7 days before trial mixes are made or, if trial mixes are not required, at least 7 days before the mix is placed in the permanent work.

Particulars of ready-mixed concrete supplier

16.19 The name of the suppliers and the location of each plant, including a back-up plant, from which the Contractor proposes to obtain ready-mixed concrete shall be submitted to the Engineer at least 14 days before trial mixes are made or, if trial mixes are not required, at least 14 days before the ready-mixed concrete is placed in the permanent work.

Particulars of batching and mixing plant

16.20 Particulars of the proposed batching and mixing plant to be used on the Site, including a layout plan and the output of the plant, shall be submitted to the Engineer at least 7 days before the plant is delivered to the Site.

Particulars of precast concrete units

16.21 (1) The following particulars of the proposed precast concrete units shall be submitted to the Engineer:

(a) details of precasting yards,

(b) a certificate showing the manufacturer's name, the date and place of manufacture, the identification numbers of the precast concrete units and including results of tests for:

- compressive strength of concrete cubes at 28 days
- routine tests, including loading tests, carried out at the precasting yards,

(c) details of lifting points and methods of handling, and

(d) procedure for testing precast units.

(2) The particulars, other than certificates, shall be submitted to the Engineer at least 14 days before the first delivery of the precast concrete units to the Site. The certificates shall be submitted for each batch of precast concrete units delivered to the Site.

Particulars of construction joints 16.22 Particulars of the proposed positions and details of construction joints in concrete which are not stated in the Contract shall be submitted to the Engineer for approval at least 14 days before the relevant elements are concreted.

TRIALS

Trial mix concrete 16.23 (1) Trial mixes are not required for designed mix concrete of Grade 20 and below, or for standard mix concrete.

(2) If test data for designed mix concrete of the proposed grade and with similar constituents and properties and produced in the plant or plants proposed to be used are submitted in accordance with Clause 16.18, and are acceptable to the Engineer, no trials for that designed mix will be required.

(3) If test data for designed mix concrete of the proposed grade and with similar constituents and properties produced in plant other than that proposed to be used are submitted in accordance with Clause 16.18, and are acceptable to the Engineer, the Engineer may require Plant Trials to be carried out in accordance with Clause 16.24.

(4) If test data for designed mix concrete produced in the plant or plants proposed to be used, but of a grade or with constituents and properties other than those proposed, are submitted in accordance with Clause 16.18, and are acceptable to the Engineer, the Engineer may require Laboratory Mix Trials to be carried out in accordance with Clause 16.25.

(5) If no test data for designed mix concrete are submitted or if test data submitted in accordance with Clause 16.18 do not in the opinion of the Engineer demonstrate the suitability of the proposed plant and mix design, the Engineer may require both Plant Trials and Laboratory Mix Trials in accordance with Clauses 16.24 and 16.25 respectively.

(6) Plant Trials and Laboratory Mix Trials shall be completed at least 35 days before the concrete mix is placed in the permanent work.

(7) The Contractor shall inform the Engineer at least 24 hours before conducting Plant Trials or Laboratory Mix Trials.

Plant Trials 16.24 (1) Plant Trials shall be made using the plant or plants proposed and the mix designs and constituents submitted to the Engineer.

(2) One batch of concrete of a proposed designed mix shall be made on each of three days in each plant proposed to be used. The batch shall be at least 60% of the mixer's nominal capacity. If the concrete is batched in a central plant and mixed in a truck mixer, three different truck mixers shall be used.

(3) Three samples of concrete shall be provided from each batch at approximately 1/6, 1/2 and 5/6 of the discharge from the mixer. Each sample shall be of sufficient size to perform a slump test or a flow table test, and make two 150mm test cubes. The method of sampling shall be as stated in CS1.

(4) Each sample taken in accordance with Clause 16.24(3) shall be tested to determine its slump value or its flow value in accordance with CS1.

COR No. 2/2005(June)

(5) Two 150 mm test cubes shall be made from each sample taken in accordance with Clause 16.24(3) and stored, cured and tested to determine the compressive strength at 28 days in accordance with CS1.

Laboratory Mix Trials 16.25 (1) Laboratory Mix Trials shall be made in the Contractor's laboratory using the mix designs and constituents submitted to the Engineer.

(2) Laboratory Mix Trials shall be carried out in accordance with Section 11 of CS1. Three separate batches shall be made, each of sufficient size to provide samples for two slump tests or two flow table tests, and to make six 150mm test cubes.

(3) Two slump tests or two flow table tests in accordance with CS1 shall be performed on separate specimens from each batch of Laboratory Trial Mix concrete.

COR No. 2/2005(June)

(4) Six 150 mm test cubes shall be made from each batch of Laboratory Trial Mix concrete, stored, cured and tested for compressive strength at 28 days in accordance with CS1.

Compliance criteria Plant Trials 16.26 The results of tests on concrete taken from Plant Trials in accordance with Clause 16.24 shall comply with the following requirements :

(a) The average of the nine slump values shall be within 20mm or 25%, whichever is the greater, of the designed slump value. The average of the nine flow values shall be within +/- 35mm of the designed flow value.

(b) The range of the three slump values for each batch of concrete shall not exceed 20% of the average of the three slump values for that batch. For flow table tests, the range of the three flow values for each batch of concrete shall be within 70mm.

COR No. 2/2005(June)

(c) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 10 MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 4 MPa.

(d) The range of the compressive strength of the six test cubes from each batch of concrete shall not exceed 20% of the average compressive strength of the six test cubes from that batch.

Compliance criteria: Laboratory Mix Trials 16.27 (1) When test data relating to the proposed plant or plants submitted in accordance with Clause 16.18 show that the plant standard deviation exceeds 5 MPa, or in the absence of acceptable data, the results of tests on Laboratory Mix Trial concrete shall comply with the following requirements:

(a) The average of the six slump values shall be within 20mm or 25%, whichever is the greater, of the designed slump value. The average of the six flow values shall be within +/- 35mm of the designed flow value.

COR No. 2/2005(June)

(b) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 12 MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 6 MPa.

(2) When test data relating to the proposed plant or plants submitted in accordance with Clause 16.18 show that the plant standard deviation does not exceed 5 MPa and the data are acceptable to the Engineer, the results of tests on Laboratory Mix Trial concrete shall comply with the following requirements :

(a) The average of the six slump values shall be within 20 mm or 25%, whichever is the greater, of the designed slump value. The average of the six flow values shall be within +/- 35mm of the designed flow value.

COR No. 2/2005(June)

(b) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 8 MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 2 MPa.

Trial lengths and trial panels 16.28 Trial lengths required in accordance with Clauses 10.23 to 10.26 and trial panels required in accordance with Clauses 14.22 and 14.23 shall be constructed for each concrete mix as appropriate.

Non-compliance: trial mix concrete 16.29 (1) If the result of any test for workability or compressive strength of laboratory mix trial and plant trial concrete does not comply with the specified requirements for the property, particulars of proposed changes to the materials, mix design or methods of production shall be submitted to the Engineer; further laboratory mix trials or plant trials shall be made until the result of every test complies with the specified requirements for workability and compressive strength of laboratory mix trial and plant trial concrete.

(2) If trial lengths or trial panels are constructed using the non-complying trial mix, further trial lengths or trial panels shall be constructed unless in the opinion of the Engineer the changes to the materials, mix design or methods of production will not affect the results of the previous trial lengths or trial panels.

Approved concrete mix 16.30 (1) A concrete mix which complies with the specified requirements for laboratory mix trials, plant trials and for trial lengths or trial panels shall become an approved concrete mix. The designed slump value or designed flow value used to produce an approved concrete mix shall become the approved slump value or approved flow value.

(2) If laboratory mix trials or plant trials are not required, a concrete mix submitted as stated in Clause 16.18 and which complies with the specified requirements for trial lengths or trial panels shall become an approved concrete mix. The designed slump value or designed flow value of the concrete mix shall become the approved slump value or approved flow value.

COR No. 2/2005(June)

Commencement of concreting 16.31 Concrete shall not be placed in the permanent work until the concrete mix has been approved by the Engineer.

Changes in materials and methods of construction 16.32 Unless permitted by the Engineer, the materials, mix design, methods of production or methods of construction used to produce an approved concrete mix shall not be changed except that the variations of cement content as stated in Clause 16.14(3), and variations in aggregate quantities within the approved tolerances, will be allowed.

HANDLING AND STORAGE OF MATERIALS

Storage of cement and PFA 16.33 (1) Cement in bags shall be stored in a dry, weatherproof store sheltered on the top and 3 sides with a raised floor. Each delivery shall be identified and kept separate and shall be used in the order of delivery.

(2) Bulk cement and PFA shall be kept dry. Cement and PFA of different types and from different sources shall be stored in separate silos clearly marked to identify the different contents of each.

Handling and storage of aggregates 16.34 (1) Aggregates shall not be handled or stored in a manner which will result in mixing of the different types and sizes or in segregation or contamination of the aggregates.

(2) Different types and sizes of aggregates shall be stored in separate hoppers or in separate stockpiles. The stockpiles shall have well drained concrete floors and shall have dividing walls of sufficient height to keep the different aggregates separate.

Storage of admixtures and curing compounds 16.35 Admixtures and curing compounds shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.

Handling and storage of precast concrete units 16.36 (1) The identification number, date of casting and lifting points shall be marked on precast concrete units in a manner agreed by the Engineer.

(2) Precast concrete units shall be lifted and supported only at the designed lifting points and shall not be subjected to rough handling, shock loading or dropping.

(3) Precast concrete units shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to the units or in contamination of the units. Precast concrete units shall be protected from damage and damaged units shall not be used in the permanent work unless permitted by the Engineer.

BATCHING AND MIXING CONCRETE

Batching concrete 16.37 (1) Measuring and weighing equipment for batching concrete shall be maintained in a clean, serviceable condition. The equipment shall be zeroed daily and calibrated when the equipment is set up on the Site and at a frequency of at least once per month. The accuracy of the measuring equipment shall be within 3% of the quantity of cementitious materials, total aggregates or water being measured and within 5% of the quantity of admixtures being measured.

(2) The quantities of cement, PFA and fine and coarse aggregate shall be measured by mass except that cement supplied in bags may be measured by using a whole number of bags in each batch. The mass of aggregates shall be adjusted to allow for the free moisture content of the aggregates.

(3) Separate weighing equipment shall be used for cementitious material and aggregates.

(4) The quantity of water shall be adjusted for the free moisture content of the aggregates and shall be measured by mass or volume.

(5) Liquid admixtures shall be measured by mass or volume and powdered admixtures shall be measured by mass.

Mixing concrete 16.38 (1) The quantities of concrete mixed and the speed of operation of a mixer shall comply with the manufacturer's recommendations.

(2) A mixer shall not be loaded in excess of its rated capacity and shall be emptied before being re-charged. A mixer which has been out of use for more than 30 minutes shall be cleaned before fresh concrete is mixed in it. Mixers shall be cleaned whenever there is a change in the type of cement being used.

(3) Mixing times or the number and rate of revolutions of mixer drums shall not be less than those recommended by the manufacturer unless it is demonstrated in the production of concrete that a shorter time or fewer or slower revolutions are adequate. Constituents shall be thoroughly mixed and admixtures shall be uniformly distributed throughout the concrete

(4) Water shall be added to truck mixed concrete at the batching plant and shall not be added in transit. Water shall not be added at the Site unless approved by the Engineer.

(5) Superplasticising admixtures used with concrete mixed off the Site shall be added at the Site unless otherwise permitted by the Engineer.

(6) Water shall not be added to partially hardened concrete.

TRANSPORTATION OF CONCRETE

Transportation of concrete 16.39 (1) Concrete shall not be transported in a manner which will result in contamination, segregation, loss of constituents or excessive evaporation.

(2) Concrete batched off the Site shall be transported to the Site in purpose-made agitators operating continuously or in truck mixers.

RECORDS OF CONCRETE

Records of concrete 16.40 (1) Delivery notes shall be provided for each delivery of concrete to the Site. The delivery notes shall be kept on the Site and shall be available for inspection by the Engineer at all times. Delivery notes shall contain the following details:

(a) serial number of delivery note,

(b) date,

(c) name and location of batching and mixing plant,

(d) registration number of delivery vehicle,

(e) name of purchaser,

(f) name and location of the Site,

(g) designation of concrete mix and approved slump value or approved flow value,

COR No. 2/2005(June)

(h) sources of constituents,

(i) quantity of concrete, and

(j) time of introduction of water to the concrete.

(2) Records of concreting operations shall be kept by the Contractor on the Site and shall be available for inspection by the Engineer at all times. Records shall contain the following details:

(a) date,

(b) designation of concrete mix and approved slump value or approved flow value,

COR No. 2/2005(June)

(c) total quantity of each concrete mix produced that day,

(d) serial number of delivery note,

(e) arrival time of delivery vehicle,

(f) time of completion of discharge,

(g) quantity of water added at the Site,

(h) position where concrete is placed,

(i) results of flow table tests or slump tests,

COR No. 2/2005(June)

(j) details of test cubes made, and

(k) temperature of concrete if a restriction on the temperature is stated in the Contract.

PLACING AND COMPACTING CONCRETE

Placing concrete

16.41 (1) The permission of the Engineer shall be obtained before concrete is placed in any part of the permanent work. If placing of concrete is not started within 24 hours of permission having been given, permission shall again be obtained from the Engineer. The Contractor shall inform the Engineer before concreting starts and shall allow the Engineer sufficient time to inspect the work which is to be concreted.

(2) Concrete shall be placed and compacted in its final position within 2½ hours of the introduction of cement to the concrete mix.

(3) Concrete which in the opinion of the Engineer is no longer sufficiently workable shall not be placed in the permanent work.

(4) Concrete shall not be placed in water other than by tremie or in bags.

(5) Concrete shall be placed as close as practicable to its final position and shall not be moved into place by vibration. Trunking or chutes shall be used to place concrete which will fall more than 2.7 m unless otherwise permitted by the Engineer.

(6) Concrete shall be placed in such a manner that the formwork, reinforcement or built-in components are not displaced.

(7) Unless otherwise permitted by the Engineer, concrete other than concrete placed by tremie shall be placed in horizontal layers to a compacted depth of not more than 450 mm if internal vibrators are used and to a compacted depth of not more than 150 mm in other cases.

(8) Concrete shall be placed continuously within the element to be concreted. Fresh concrete shall not be placed against concrete which has been in position for more than 30 minutes unless in the opinion of the Engineer the concrete already placed is sufficiently workable and the permission of the Engineer has been obtained. If permission is not obtained, a construction joint shall be formed as stated in Clause 16.45; concrete shall not be placed against the concrete already placed for at least 24 hours unless permitted by the Engineer.

Placing concrete by pumping

16.42 (1) Concrete pumps shall be operated and maintained in accordance with the manufacturer's recommendations. The pumps and pipelines shall be maintained in a clean condition. Internal surfaces of pipelines shall not be aluminium. Joints in pipelines shall be tightly fixed and shall not permit grout loss.

(2) Concrete pumps shall be positioned such that pipelines are as short and straight as practicable and require as little repositioning as practicable. Bends in pipelines shall be arranged in such a manner that the concrete, formwork, reinforcement or built-in components are not disturbed.

(3) Pipelines shall be lubricated by passing cement grout or concrete through the pipeline before the concrete is pumped. The initial discharge of pumped concrete shall not be placed in the permanent work.

Placing concrete by tremie

16.43 (1) Tremies used to place concrete shall be securely supported in position and the joints shall be watertight. A temporary seal of a type agreed by the Engineer shall be used to keep the water and the concrete separate at the start of concreting.

(2) After the concrete is flowing, the tremie shall be raised in a manner agreed by the Engineer; the lower end of the tremie shall be kept immersed in the concrete to a depth of at least 1 m. Water, mud and other deleterious material shall be prevented from entering the tremie after concreting has started.

(3) If the tremie becomes blocked or is removed from the concrete, concreting shall be stopped immediately unless otherwise permitted by the Engineer. Concreting shall not recommence for at least 24 hours unless permitted by the Engineer; contaminated concrete shall be removed before concreting recommences.

(4) Concrete placed by tremie shall be placed above the specified level by an amount which is sufficient to allow for the removal of contaminated concrete; contaminated concrete shall be removed.

Compacting concrete

16.44 (1) Concrete shall be compacted to form a dense homogeneous mass.

(2) Unless otherwise permitted by the Engineer, concrete shall be compacted by means of internal vibrators of suitable diameter. A sufficient number of vibrators shall be maintained in serviceable condition on the Site to ensure that spare equipment is available in the event of breakdown.

(3) Vibrators shall be used in such a manner that vibration is applied continuously and systematically during placing of the concrete until the expulsion of air has practically ceased; vibrators shall not be used in a manner which will result in segregation. Internal vibrators shall be inserted to the full depth of the concrete placed and shall be withdrawn slowly.

(4) Vibration shall not be applied by way of the reinforcement, and contact between internal vibrators and formwork, reinforcement or built-in components shall be avoided as far as possible. Concrete shall be vibrated in such a manner that the formwork, reinforcement or built-in components will not be displaced.

(5) Concrete which has been in position for more than 30 minutes shall not be vibrated except as stated in Clause 16.41(8).

(6) No-fines concrete shall be compacted using a minimum amount of punning.

CONSTRUCTION JOINTS

Construction joints 16.45 (1) Construction joints in concrete shall be formed only at the specified positions and by the specified method unless otherwise approved by the Engineer. The position and details of construction joints which are not stated in the Contract shall be arranged in such a manner that the possibility of the occurrence of shrinkage cracks is minimised.

(2) Construction joints shall be normal to the axis or plane of the element being constructed unless otherwise permitted by the Engineer.

(3) Waterstops shall be provided at construction joints in water retaining structures and water tight structures.

(4) Laitance and loose material shall be removed from the surface of construction joints and the aggregate shall be exposed by a method agreed by the Engineer. The work shall be carried out as soon as practicable after the concrete has hardened sufficiently for the cement matrix to be removed without disturbing the coarse aggregate. The surface of the construction joint shall be cleaned after the matrix has been removed.

(5) The surface of the construction joint shall be clean and dry when fresh concrete is placed against it.

CURING CONCRETE

Curing concrete 16.46 (1) Concrete shall be protected against harmful effects of weather, running water and drying out by one of the following methods:

Method 1 : A liquid curing compound shall be applied to the concrete surface by a low-pressure spray until a continuous visible covering is achieved.

Method 2 : The concrete surface shall be covered with hessian, sacking, canvas or other absorbent material agreed by the Engineer or with a layer of fine aggregate at least 25 mm thick; the hessian, sacking, canvas, absorbent material or fine aggregate shall be kept constantly wet.

Method 3 : The concrete surface shall be covered with polyethylene sheeting; concrete surfaces which have become dry shall be thoroughly wetted before the sheeting is placed.

Method 4 : Unformed concrete surfaces shall be covered with polyethylene sheeting until the concrete has hardened sufficiently for water curing to be carried out. Water curing shall be carried out by spraying the concrete surface continuously with cool water or by ponding immediately after the sheeting is removed. If in the opinion of the Engineer water curing is impracticable, Method 2 shall be used instead of water curing.

(2) Method 1 shall not be used on concrete surfaces against which concrete will be placed or which will have a Class T1 finish or which will

be painted or tiled.

(3) Method 1, 2, 3 or 4 shall be carried out on unformed concrete surfaces immediately after the concrete has been compacted and finished. Method 1, 2 or 3 shall be carried out on formed concrete surfaces immediately after the formwork has been removed.

(4) Polyethylene sheeting shall be impermeable and shall have a nominal thickness of 0.125 mm.

(5) Hessian, sacking, canvas, absorbent material and polyethylene sheeting shall be lapped and securely held in position in such a manner that the concrete surface will not be damaged.

(6) Cold water shall not be applied to concrete surfaces or formwork intermittently in large quantities.

(7) The different methods of protection shall be maintained for the minimum periods stated in Table 16.5 after the concrete has been placed. The minimum periods may be reduced by the number of days during which formwork is left in position.

Table 16.5: Minimum periods of protection for concrete

Type of structure	Method of protection	Minimum period of protection (days)	
		Concrete not containing PFA or PPFAC	Concrete containing PFA or PPFAC
Water retaining structures and water tight structures	1	7	7
	2, 3 or 4	7	9
Others	1	7	7
	2, 3 or 4	4	5

INSTALLATION OF PRECAST CONCRETE UNITS

Installation of precast concrete units 16.47 (1) Contact surfaces between in-situ concrete and precast concrete units shall be prepared as stated in the Contract. Dimensional tolerances shall be checked before the precast concrete units are lifted into position.

(2) Temporary supports and connections shall be provided as soon as practicable during installation of precast concrete units.

(3) Final structural connections shall be completed as soon as practicable after the precast concrete units have been installed.

(4) Levelling devices which have no load bearing function in the finished structure shall be slackened, released or removed after the precast concrete units have been installed.

LOADING OF CONCRETE

Loading of concrete 16.48 (1) Loads which will induce a compressive stress in the concrete exceeding one-third of the compressive strength of the concrete at the time of loading or exceeding one-third of the grade strength, whichever is less, shall not be applied to concrete; allowance shall be made for the weight of the concrete in determining the loading. The strength of the concrete and the stresses produced by the loads shall be assessed by a method agreed by the Engineer.

(2) Loads from materials not forming part of the permanent work or from Constructional Plant or other vehicles shall not be applied to no-fines concrete.

TESTING: CEMENT, PFA, AGGREGATE, ADMIXTURE, CURING COMPOUND, RECYCLED WATER

COR No. 1/2003(March)

Batch: cement, PFA, aggregate, admixture, curing compound 16.49 A batch of cement, PFA, aggregate, admixture or curing compound is any quantity of cement, PFA, aggregate, admixture or curing compound of the same type, manufactured or produced at the same time in the same place, covered by the same certificates and delivered to the Site, or stored at the ready-mixed concrete plant, at any one time.

Samples: cement, PFA, aggregate, admixture, curing compound 16.50 (1) One sample of each type of cement, PFA, aggregate, admixture and curing compound shall be provided at the same time as particulars of the material are submitted to the Engineer.

(2) The size of each sample and the method of sampling shall be as stated in Table 16.6.

Testing: cement, PFA, aggregate, admixture, curing compound, recycled water 16.51 (1) Each sample of cement, PFA, aggregate, admixture and curing compound shall be tested to determine the properties stated in Table 16.7.

COR No. 1/2003(March)

(2) The method of testing shall be as stated in Table 16.7.

(3) The maximum total chloride content of concrete shall be determined on the basis of the results of tests for chloride content of each constituent.

(4) If recycled water is used for mixing concrete, tests shall be carried out according to the methods and frequency stated in Table 16.7A.

COR No. 1/2003(March)

Table 16.6: Size of samples and method of sampling cement, PFA, aggregate, admixture and curing compound

Material	Size of sample	Method of sampling
Cement	20 kg	BS 4550: Part 1
PFA	20 kg	BS 4550: Part 1
Coarse aggregate	25 kg	BS 812: Part 102
Fine aggregate	10 kg	BS 812: Part 102
Admixture (powdered)	1 kg	BS 5075: Part 1
Admixture (liquid)	1 L	BS 5075: Part 1
Curing compound	5 L	BS 5075: Part 1

Table 16.7: Methods of testing cement, PFA, aggregate, admixture and curing compound

Material	Property	Method of testing
OPC, RHPC, SRPC, PPFAC	Chemical composition	BS 4550: Part 2
	Fineness Compressive strength at 3, 7 and 28 days Initial and final setting times Soundness	BS 4550: Part 3
PPFAC	Proportion by mass of PFA	BS 6588
PFA	Chemical composition	BS 3892: Part 1
	Fineness Moisture content	BS 3892: Part 1
Coarse aggregate, fine aggregate	Grading	BS 812: Part 103
	Silt content	BS 812: Part 1
	Chloride content	BS 812: Part 117
Coarse aggregate	Flakiness index Ten percent fines Water absorption	BS 812: Part 105.1 BS 812: Part 111 BS 812: Part 2
Admixture	Chloride content	BS 5075: Part 1
Curing compound	Efficiency index	Appendix 16.1

Table 16.7A: Recycled water testing for each batching plant location

			Test frequency
(a) Density test for recycled water (b) Initial setting time of cement with recycled water (time of set, deviation from control, h:min)	≤ 1030 kg/m^3 From 1:00 earlier to 1:30 later		
Chemical test for recycled water **COR No. 1/2005** (a) Chloride content (as C1): - prestressed concrete steam-cured structural concrete - concrete with reinforcement or other embedded metal (b) Sulphate content (as SO_4) (c) Acid-soluble alkali content	 500 ppm 1,000 ppm 3,000 ppm 600 ppm	 APHA 4500-C1-B, 18th Edition (1992) APHA 4500-Cl-B, 18th Edition (1992) APHA 4500-SO42-C, 18th Edition (1992) APHA 3500-K-C & 3500-Na-C, 18th Edition (1992)	For all tests: (i) Once per week for the first 2 months (ii) Once per month for the next 12 months thereafter (iii) In case of a weekly or monthly test indicates that the limits are exceeded, the water shall immediately be suspended for use in concrete mixing until two sets of consecutive test results taken from the same source are satisfactory. In such case, the testing frequency shall be maintained at or reverted back to once per week until two sets of consecutive test results are satisfactory. (iv) The testing frequency shall be subject to review after the 12-month period for the monthly test

Notes: 1. Test method to be proposed by the Contractor for the acceptance of the Engineer.
2. Laboratories accredited by HOKLAS for the relevant tests shall be used, if available, in which case results shall be issued on HOKLAS endorsed test reports.
COR No. 1/2005

TESTING: CONCRETE - GENERAL REQUIREMENTS

Batch: concrete 16.52 A batch of concrete is any quantity of concrete produced in one cycle of operations of a batch mixer, or conveyed ready-mixed in a delivery vehicle, or discharged during one minute from a continuous mixer.

Reduction of testing frequency 16.53 The number of tests for workability or compressive strength of standard mix concrete may be reduced if in the opinion of the Engineer the standard of quality control is satisfactory.

TESTING: CONCRETE - WORKABILITY

Samples: workability of concrete 16.54 (1) One sample of concrete shall be provided from each batch of concrete to determine the workability of the concrete.

(2) The size of each sample and the method of sampling shall be in accordance with CS1. **COR No. 2/2005(June)**

Testing: workability of concrete 16.55 (1) Each sample of concrete taken as stated in Clause 16.54 shall be divided into two specimens; each specimen shall be tested to determine the workability of the concrete in accordance with CS1. Selection of the testing method is given in the table below:

Normal Workability (slump value from 80 mm to 140mm)	High Workability (flow value from 420 mm to 600mm)
Slump Test	Flow Table Test (See Note below)

Note: For concrete with a flow value greater than 600mm, the Engineer shall specify the workability testing method.

(2) The average of the two workability values shall be calculated and referred to as the average slump value or average flow value. **COR No. 2/2005(June)**

Compliance criteria: workability of concrete 16.56 (1) The average slump value of the two specimens taken from one sample of standard mix concrete shall be within the appropriate range stated in Table 16.3.

(2) The average slump value of the two specimens taken from one sample of designed mix concrete shall be within 25 mm or 33% of the approved slump value, whichever is the greater.

(3) The average flow value of the two specimens taken from one sample of designed mix concrete shall be within +/- 50mm of the approved flow value. **COR No. 2/2005(June)**

Non-compliance: workability of concrete 16.57 A batch of concrete shall be considered as not complying with the specified requirements for workability if the result of any test for workability, carried out on a sample taken from the batch, does not comply with the specified requirements for workability.

TESTING: CONCRETE - COMPRESSIVE STRENGTH

Samples: compressive strength of concrete 16.58 (1) For each concrete mix, one sample of concrete shall be provided from each amount of concrete as stated in Table 16.8 or from the amount of concrete produced each day, whichever is less.

(2) If the Contractor requests, or if the Engineer instructs, that the concrete be tested for compressive strength at ages other than 28 days, additional samples shall be provided. The number of additional samples shall be as stated in Clause 16.58(1).

(3) The size of each sample and the method of sampling shall be in accordance with CS1. If a superplasticising admixture is included in the

concrete mix, the samples shall be taken after the superplasticiser is added and after the concrete is remixed.

Table 16.8: Rate of sampling of concrete

Type of structure	Amount of concrete
Masts Cantilevers 3 m or more in length Columns Shear walls Prestressed elements Other critical elements	10 m^3 or 10 batches, whichever is less
Solid rafts Pile caps Mass concrete	100 m^3 or 100 batches, whichever is less
Other types	25 m^3 or 25 batches, whichever is less

Testing: compressive strength of concrete

16.59 (1) Two 150 mm test cubes shall be made from each sample of concrete taken as stated in Clause 16.58. Each pair of test cubes shall be tested to determine the compressive strength at 28 days.

(2) The method of making test cubes shall be in accordance with CS1.

(3) The method of storing test cubes shall be in accordance with CS1. Test cubes which are cured on the Site shall be delivered to the testing laboratory at least 48 hours before the tests are due to be carried out.

(4) The method of testing shall be in accordance with CS1.

(5) For the purpose of assessing compliance of designed mix concrete as stated in Clauses 16.61 and 16.62, the average of the two compressive strengths of the pair of test cubes shall be calculated and referred to as the test result.

Non-compliance: compressive strength of standard mix concrete

16.60 If the result of any test for compressive strength at 28 days of standard mix concrete is less than the grade strength, the Engineer may instruct that tests as stated in Clauses 16.63 to 16.66 are carried out on concrete cores or on samples taken from the hardened concrete.

Compliance criteria: compressive strength of designed mix concrete

16.61 (1) The results of tests for compressive strength at 28 days of designed mix concrete shall comply with the following requirements:

(a) Each test result shall not be less than the grade strength by more than the appropriate amount stated in Column A of Table 16.9, and,

(b) The average of any four consecutive test results, or the average of the first two or first three test results if less than four test results are available, shall exceed the grade strength by at least the appropriate amount stated in Column B of Table 16.9.

Table 16.9: Compliance criteria for compressive strength of designed mix concrete

Grade strength (MPa)	Compliance criteria	Column A	Column B
		Maximum amount by which each test result may be below the grade strength (MPa)	Minimum amount by which the average of any four consecutive test results shall be above the grade strength (MPa)
20 or greater	C1	3	5
	C2	3	3
below 20	C3	2	2

(2) If there is a period exceeding 14 days between any two consecutive test results in any group of four consecutive test results and if agreed by the Engineer, the test results immediately before and immediately after the period may be treated separately for the purpose of Clause 16.61(1)(b).

(3) If the difference between the compressive strengths of two test cubes made from one sample of designed mix concrete exceeds 15% of the test result:

(a) the higher of the compressive strengths of the two test cubes shall be used to assess compliance as stated in Clause 16.61(1)(a), and

(b) the test result for that sample shall not be used to assess compliance as stated in Clause 16.61(1)(b) and shall not be used to calculate the standard deviation.

(4) For designed mix concrete with a grade strength of less than 20 MPa, compliance criteria C3 shall apply.

(5) For designed mix concrete with a grade strength of 20 MPa or greater, until 40 test results are available either:

(a) compliance criteria C1 shall apply, or

(b) if in the opinion of the Engineer there is sufficient evidence that the standard of quality control using similar materials and plant is such that the standard deviation for at least 40 test results will not exceed 5 MPa, compliance criteria C2 shall apply.

(6) For designed mix concrete with a grade strength of 20 MPa or greater, the standard deviation of test results shall be calculated after every test result for each designed mix using the last 40 test results judged by the same compliance criteria. If the standard deviation does not exceed 5 MPa, compliance criteria C2 shall apply to subsequent test results. If the standard

deviation exceeds 5 MPa and does not exceed 8 MPa, compliance criteria C1 shall apply to subsequent test results. If the standard deviation exceeds 8 MPa, no further concrete shall be placed in the permanent work until an investigation of the materials, mix design, methods of production, sampling and testing has been carried out and measures have been taken which in the opinion of the Engineer will result in restoring a satisfactory standard of quality control.

(7) If the compliance criteria are changed from C1 to C2 or from C2 to C1, the new compliance criteria shall apply from the 35th day after making the last pair of test cubes in the set of 40 on which the decision to change was based. For the purpose of Clause 16.61(1)(b), test results immediately before and immediately after the change shall be treated separately.

Non-compliance: compressive strength of designed mix concrete

16.62 (1) A batch of designed mix concrete shall be considered as not complying with the specified requirements for compressive strength if the test result for the pair of test cubes made from a sample taken from the batch does not comply with the requirements stated in Clause 16.61(1)(a).

(2) The batches of designed mix concrete from which the first and last samples in any group of four consecutive test results were taken and all intervening batches shall be considered as not complying with the specified requirements for compressive strength if the group of four consecutive test results does not comply with the requirements stated in Clause 16.61(1)(b).

(3) If designed mix concrete is considered as not complying with the specified requirements for compressive strength, the Engineer may instruct that tests as stated in Clauses 16.63 to 16.66 are carried out on concrete cores or on samples taken from the hardened concrete.

TESTING: HARDENED CONCRETE

Samples: hardened concrete and concrete cores

16.63 (1) The number of samples, including cores, of hardened concrete to be provided for testing shall be as stated in the Contract or, if testing is to be carried out as a result of the concrete not complying with the specified requirements, shall be as instructed by the Engineer. In the latter case, all the concrete being investigated shall be divided as instructed by the Engineer into separate test locations. The number of samples taken from each location shall be as instructed by the Engineer and the quality of concrete at each location shall be assessed separately. The positions from which the samples are taken shall be as instructed by the Engineer.

(2) The size of samples and the method of sampling shall be in accordance with CS1.

Testing: concrete cores

16.64 (1) Each concrete core shall be inspected for evidence of segregation of the constituents and for the presence of voids. Specimens selected from each core shall be tested to determine the compressive strength.

(2) The method of preparing and inspecting concrete cores and of testing the cores to determine the compressive strength shall be in accordance with CS1. Concrete cores shall not be tested for compressive strength until the concrete has reached an age of 28 days.

Compliance criteria: concrete cores

16.65 (1) The concrete core shall be considered as non-compliant if it exhibits honeycombing which means interconnected voids arising from, for example, inadequate compaction or lack of mortar.

(2) The results of tests for compressive strength of concrete cores shall be interpreted in accordance with BS 6089. Adjustments to the measured strength in respect of the age of the core when tested shall not be made unless permitted by the Engineer. The estimated in-situ cube strength of each core specimen shall be calculated in accordance with CS1. For any set of cores representing a test location, the average estimated equivalent cube strength shall be at least 85% of the specified grade strength, and each individual estimated equivalent cube strength shall be at least 75% of the specified grade strength.

Analysis of hardened concrete

16.66 (1) Each sample of hardened concrete shall be tested to determine the properties or the composition of the concrete as stated in the Contract or, if testing is to be carried out as a result of the concrete not complying with the specified requirements, shall be tested as instructed by the Engineer.

(2) Tests on hardened concrete shall be carried out within 14 days of the Engineer's instruction for the test.

(3) The method of testing shall be in accordance with CS1.

TESTING: PRECAST UNITS

Batch: precast units

16.67 A batch of precast units is any quantity of precast units, including prestressed units, of the same type and size, of the same concrete mix, manufactured in the same place, covered by the same certificates and delivered to the Site at any one time.

Samples: precast units

16.68 The number of precast units to be provided for testing from each batch shall be as stated in the Contract.

Testing: precast units

16.69 (1) Load tests shall be carried out to determine the deflection and recovery of each precast unit, including prestressed units, provided for testing and to determine the resistance to cracking of each prestressed unit provided for testing.

(2) Load tests shall be carried out in accordance with a procedure agreed by the Engineer. The age at which the units are to be tested, the test load, the points at which the loads are to be applied and the points at which the unit is to be supported shall be as stated in the Contract.

(3) The method of testing shall be as stated in Appendix 16.2.

(4) Post-tensioned units shall not be tested until at least 7 days after the ducts have been grouted.

Compliance criteria: precast units

16.70 The results of load tests on precast units shall comply with the requirements stated in the Contract.

PART 2: JOINTS IN CONCRETE

GENERAL

General requirements 16.71 The works and materials specified in Clauses 16.72 and 16.73 shall comply with the sections stated, unless otherwise stated in this Section.

Joints in concrete carriageways 16.72 Joints in concrete carriageways shall comply with Section 10.

Construction joints 16.73 Construction joints in concrete shall comply with Section 16.

MATERIALS

Materials for joints in water retaining structures and water tight structures 16.74 (1) Materials for joints in water retaining structures and water tight structures for sewage and effluent treatment shall be resistant to aerobic and anaerobic microbiological attack and resistant to attack by petrol, diesel oil, dilute acids and alkalis.

(2) Materials for joints in water retaining structures for potable and fresh water shall comply with the requirements of BS 6920.

Joint filler 16.75 Joint filler shall be a proprietary type approved by the Engineer and shall be a firm, compressible, single-thickness, non-rotting filler; joint filler for joints in water retaining structures and water tight structures shall be non-absorbent.

Bitumen emulsion 16.76 Bitumen emulsion for joints in water retaining structures and water tight structures shall comply with BS 3416. Bitumen emulsion for surfaces against which potable or fresh water will be stored or conveyed shall comply with BS 3416, type II.

Joint sealant 16.77 (1) Joint sealant shall be a grade suited to the climatic conditions of Hong Kong and shall perform effectively over a temperature range of 0°C to 60°C. Joint sealant for exposed joints shall be grey.

(2) Joint sealant other than cold-applied bitumen rubber sealant shall be:

(a) a gun grade for horizontal joints 15 mm wide or less and for vertical and inclined joints,

(b) a pouring grade for horizontal joints wider than 15 mm.

(3) Polysulphide-based sealant shall be a cold-applied two-part sealant complying with BS 4254. Polysulphide-based sealant for expansion joints in water retaining structures and water tight structures shall have a transverse butt-joint movement range of at least 20%.

(4) Polyurethane-based sealant shall be a cold-applied two-part sealant complying with the performance requirements of BS 4254.

(5) Hot-applied bitumen rubber sealant shall comply with BS 2499, type N1.

(6) Cold-applied bitumen rubber sealant shall be a proprietary type

approved by the Engineer.

(7) Joint sealant for joints in water retaining structures and water tight structures shall be as stated in Table 16.10.

(8) Primers and caulking material for use with joint sealant shall be a proprietary type recommended by the joint sealant manufacturer and approved by the Engineer.

(9) Different types of joint sealant and primers which will be in contact shall be compatible.

Table 16.10 : Joint sealant for water retaining structures and water tight structures

Structure for retaining/excluding	Type of joint	Type of joint sealant
Sewage	All joints	Polyurethane-based
Other than sewage	Expansion joints	Polysulphide-based or polyurethane-based
	Horizontal joints other than expansion joints	Hot-applied bitumen rubber, polysulphide-based or polyurethane-based
	Vertical and inclined joints other than expansion joints	Polysulphide-based, polyurethane-based or cold-applied bitumen rubber

Bond breaker tape 16.78 Bond breaker tape shall be a proprietary type recommended by the joint sealant manufacturer and approved by the Engineer. The tape shall be a polyethylene film with adhesive applied on one side and shall be the full width of the groove.

Bearing strip for sliding joints 16.79 Bearing strip for sliding joints shall consist of two plastic strips of a proprietary type approved by the Engineer. The strips shall be resistant to all weather conditions and to chemicals to which the structure will be subjected without impairing the reaction, durability or function of the strips. The strips shall be a type which will not require maintenance after installation. The strips shall be capable of withstanding a vertical load of at least 300 kN/m2 and shall have a maximum coefficient of friction of 0.3 under a constant shearing force.

Waterstops 16.80 Waterstops, including intersections, reducers and junctions, shall be a proprietary type approved by the Engineer. Waterstops shall be natural or synthetic rubber or extruded polyvinyl chloride and shall have the properties stated in Table 16.11.

Table 16.11: Properties of waterstops

Property	Rubber waterstops	PVC waterstops
Density	1100 kg/m^3 (± 5%)	1300 kg/m^3 (± 5%)
Hardness	60 - 70 IRHD	70 – 90 IRHD
Tensile strength	≥ 20 N/mm^2	≥ 13 N/mm^2
Elongation at break point	≥ 450%	≥ 285%
Water absorption	≤ 5% by mass after 48 hours immersion	≤ 0.15% by mass after 24 hours immersion
Softness number	-	42 - 52

SUBMISSIONS

Particulars of materials for joints 16.81

(1) The following particulars of the proposed materials for joints shall be submitted to the Engineer:

(a) manufacturer's literature and a certificate for joint filler showing the manufacturer's name, the date and place of manufacture and showing that the joint filler complies with the requirements stated in the Contract and including results of tests for:
- disintegration and shrinkage
- recovery value and reduction in mass
- extrusion,

(b) manufacturer's literature and a certificate for bitumen emulsion showing the manufacturer's name, the date and place of manufacture and showing that the bitumen emulsion complies with the requirements stated in the Contract,

(c) manufacturer's literature for joint sealant, including details of the method and time required for mixing the different components, and a certificate showing the manufacturer's name, the date and place of manufacture and showing that the sealant complies with the requirements stated in the Contract and including results of tests as appropriate for:

- rheological properties
- plastic deformation
- adhesion and tensile modulus
- application life
- adhesion in peel
- loss of mass after heat ageing
- staining

- transverse butt joint movement range
- extension
- flow
- penetration
- degradation,

(d) manufacturer's literature and a certificate for bearing strip for sliding joints showing the manufacturer's name, the date and place of manufacture and showing that the strips comply with the requirements stated in the Contract and including results of tests for:
- vertical load
- coefficient of friction,

(e) manufacturer's literature for waterstops, including details of intersections, reducers and junctions, and a certificate showing the manufacturer's name, the date and place of manufacture and showing that the waterstops comply with the requirements stated in the Contract and including results of tests for:
- density
- hardness
- tensile strength
- elongation at break point
- water absorption
- softness number of PVC waterstops, and

(f) particulars of primers and caulking material for joint sealant and of bond breaker tape.

(2) The particulars, including certificates, shall be submitted to the Engineer at least 14 days before the first delivery of the material to the Site. Certificates shall be submitted for each batch of the material delivered to the Site.

Samples of materials 16.82 Samples of the following proposed materials shall be submitted to the Engineer at the same time as particulars of the material are submitted:

(a) joint filler,

(b) bond breaker tape,

(c) bearing strip for sliding joints, and

(d) waterstops, including intersections, reducers and junctions.

STORAGE OF MATERIALS

Storage of materials for joints 16.83 (1) Bitumen emulsion, joint sealant and primer for joint sealant shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.

(2) Joint filler, bond breaker tape and waterstops shall be stored in accordance with the manufacturers' recommendations in a dry weatherproof store with a raised floor; absorbent joint filler shall be stored in sealed plastic bags and shall not be exposed to moisture or air.

(3) Bearing strip for sliding joints supplied in rolls of 5 m length or less shall be unrolled immediately after delivery and shall be stored flat at full length on an even surface; bearing strip supplied in rolls of more than 5 m length may be left in the original packing. Bearing strip shall be stored in accordance with the manufacturer's recommendations and shall be protected from mechanical damage and creasing; the two layers of strip shall be kept free from deleterious material.

FORMING JOINTS

Forming joints 16.84 (1) Materials for joints shall be used in accordance with the manufacturers' recommendations or as otherwise stated in the Contract.

(2) Joint filler shall be cut to size before fixing and shall be securely fixed in position to the existing concrete surface before concreting. There shall be no gaps between the joint filler and formation.

(3) Waterstops shall be securely fixed in position to formwork in such a manner that compaction of the concrete will not be affected. In-situ joints in waterstops shall be made using methods and equipment recommended by the manufacturer. Exposed waterstops shall be protected from exposure to conditions which may affect the waterstop and shall be kept free from rust, hydrocarbons and other deleterious material.

(4) Joints shall be formed in straight lines perpendicular to the surface of the concrete unless otherwise stated in Contract.

Forming grooves 16.85 (1) Grooves for joint sealant shall be straight and shall be perpendicular to the surface of the concrete. The bottom of the groove shall be flat and shall be parallel to the surface of the concrete.

(2) Grooves shall be formed by using timber or other approved formers and shall not be formed by cutting back or raking out the joint filler. The grooves shall be located over the joint filler such that the upper surface of the joint filler is entirely contained in the groove.

Protection of grooves 16.86 Before permanent sealing, grooves for joint sealant shall be protected from contamination by a temporary sealing strip or cover or by other methods agreed by the Engineer.

Sealing joints 16.87 (1) The permanent sealing of joints shall be carried out at least 7 days after concreting unless otherwise permitted by the Engineer.

(2) Immediately before permanent sealing, timber formers, temporary seals, dirt and loose material shall be removed from the groove and the sides of the groove shall be cleaned and roughened by water jetting, sand blasting or by other methods agreed by the Engineer.

(3) Caulking material shall be firmly packed in the bottom of the groove if the joint sealant is not required to extend to the bottom of the groove.

(4) Bond breaker tape shall be fixed continuously and evenly along the bottom of the groove for the full width and length of the groove.

(5) Concrete surfaces within 75 mm of the edges of the joint shall be masked with tape before the primer is applied and until the sealing of the joint is complete.

(6) Primer for the joint sealant shall be applied to the sides of the groove in accordance with the manufacturer's recommendations.

(7) Joint sealant shall be applied between the minimum and maximum drying times of the primer recommended by the manufacturer. The components of the sealant shall be thoroughly mixed in accordance with the manufacturer's recommendations using a power operated paddle mixer for sufficient time to produce a homogeneous mass without entrapped air. The sealant shall be dispensed into the groove as soon as practicable after mixing and within the time recommended by the manufacturer.

(8) The groove shall be clean and dry at the time of applying the primer and joint sealant.

(9) Excess joint sealant shall be removed by using a purpose made finishing tool such that the finished surface of the sealant is between 4 mm and 6 mm below the face of the concrete.

TOLERANCES

Tolerances: joints 16.88 (1) The best fit straight line of straight joints shall be within 25 mm of the specified line. The line of straight joints shall be within 10 mm of the best fit straight line.

(2) The best fit curved line of curved joints shall be as agreed by the Engineer and shall be within 25 mm of the specified line. The line of curved joints shall be within 10 mm of the best fit curved line.

(3) Joints shall be continuous across intersections of joints to within 5 mm of the best fit straight lines or best fit curved lines of each joint.

(4) The depth of grooves for joint sealant shall be within 3 mm of the specified depth.

TESTING: MATERIALS FOR JOINTS

Batch: joint filler, joint sealant, waterstops

16.89 A batch of joint filler, joint sealant or waterstop is any quantity of joint filler, joint sealant or waterstop of the same type, manufactured by the same manufacturer, covered by the same certificates and delivered to the Site at any one time.

Samples: joint filler, joint sealant, waterstops

16.90 (1) One sample of each type of joint filler, joint sealant or waterstop shall be provided at the same time as particulars of the material are submitted to the Engineer. Unless otherwise permitted by the Engineer, one sample of each type of material shall be provided from each batch of the material delivered to the Site. Unless otherwise permitted by the Engineer, one sample of mixed joint sealant shall be provided on each day that joints are sealed.

(2) The size of each sample of joint filler shall be sufficient to permit all tests stated in Appendix 16.3 to be carried out.

(3) Samples of unmixed joint sealant and primers for joint sealant shall be taken from sealed containers delivered to the Site. Samples of mixed joint sealant shall be taken immediately before the sealant is applied to the joint. The method of sampling shall be as stated in BS 2499, Appendix A. The size of each sample shall be as follows:

(a) unmixed joint sealant : 1 kg

(b) mixed joint sealant : 1.5 kg

(c) primer for joint sealant : 1 L.

(4) The size of each sample of waterstop shall be 1 m.

Testing: joint filler, joint sealant, waterstops

16.91 (1) If required by the Engineer, samples of joint filler shall be tested to determine the disintegration and shrinkage, the recovery value and reduction in mass and the extrusion. The method of testing shall be in accordance with Appendix 16.3.

(2) If required by the Engineer, samples of joint sealant shall be tested to determine the properties stated in Table 16.12. The method of testing shall be as stated in Table 16.12.

(3) If required by the Engineer, samples of waterstop shall be tested to determine the properties stated in Table 16.13. The method of testing shall be as stated in Table 16.13.

Table 16.12: Testing joint sealant

Type of joint sealant	Properties to be tested	Method of testing
Polysulphide-based sealant Polyurethane-based sealant	Rheological properties Plastic deformation Adhesion and tensile modulus Application life Adhesion in peel Loss of mass after heat ageing Staining	BS 4254
Hot-applied bitumen rubber sealant	Extension Flow Penetration Degradation	BS 2499

Table 16.13: Testing waterstops

Property	Method of testing	
	Rubber waterstops	PVC waterstops
Density	BS 903: Part A1	ISO 1183
Hardness	BS 903: Part A26	BS 2782: Part 3, Method 365D
Tensile strength	BS 903: Part A2 and BS 903: Part A5	BS 2782: Part 3, Methods 320A to 320F
Elongation at break point	BS 903: Part A2 and BS 903: Part A5	BS 2782: Part 3, Methods 320A to 320F
Water absorption	BS 903: Part A18	BS 2782: Part 4, Methods 430A to 430D
Softness number	-	BS 2782: Part 3, Method 365A

Compliance criteria: joint filler

16.92 The results of tests on joint filler shall comply with the following requirements:

(a) None of the three specimens in the weathering test shall show any sign of disintegration or shrinkage.

(b) Each of the four specimens in the compression and recovery test shall have a recovery value of at least 70%, and the reduction in mass of each of the two new specimens shall not exceed 1%.

(c) The extrusion of the free edge of the specimen shall not exceed 6 mm as determined by the extrusion test

---

.

APPENDIX 16.1

DETERMINATION OF THE EFFICIENCY INDEX OF CURING COMPOUNDS

Scope 16.1.1 This method covers the determination of the efficiency index of membrane forming curing compounds for concrete.

Materials 16.1.2 The following materials are required:

(a) Ordinary Portland cement complying with BS 12, specially selected for testing admixtures and identified as 'CAA/BS 5075: Part 1 Reference Portland Cement'; the cement shall be stored in an airtight container.

(b) Oven-dry natural sand with a rounded particle shape complying with BS 882 and with the grading stated in Table 16.1.1.

(c) Petroleum jelly, mineral oil or a propriety release agent.

Table 16.1.1: Grading of sand

BS test sieve	Percentage by mass passing
1.18 mm	100
600 μm	90 - 100
300 μm	12 - 40
150 μm	0 - 6

Apparatus 16.1.3 The following apparatus is required:

(a) Moulds constructed of corrosion resistant metal. The moulds shall be watertight, tapered and constructed so as to prevent distortion and shall have the following dimensions:

- internal size (top) : 150 mm (0mm to +5 mm) x 300 mm (0mm to +5 mm)
- internal size (bottom) : 145 mm (0mm to +5 mm) x 295 mm (0mm to +5 mm)
- internal depth : 50 mm ± 2 mm
- side and end slope : 5% ± 1%
- top flange width : at least 12 mm.

(b) A balance readable and accurate to 0.1 g.

(c) A cabinet complying with BS 2648 capable of storing specimens at a

temperature of 38°C ± 1°C and at a relative humidity of 35% ± 5%. The cabinet shall have three perforated or mesh shelves each capable of supporting two specimens during test so as to ensure a clear space of at least 40 mm on all sides of individual specimens. The cabinet shall be equipped to circulate air over the specimens at an approximate rate of 0.5 m/s.

(d) Spray equipment, such as the Wagner model W320 electric spray gun, designed to permit the curing compound to be aspirated and applied evenly to the specimen.

(e) An electrically driven mixer complying with Clause 8.3 of BS 4551 and having a nominal capacity of 12 kg.

(f) A vibrating table or a vibrating hammer with a 40 mm square foot or a compacting bar made of non-absorbent material, approximately 200 mm long and with a 40 mm square foot.

(g) A metal screed, 148 mm long, of L-shaped Section 50 mm x 25 mm with the shorter side having a sharpened leading edge. The screed shall be supported across the top of the mould by a 200 mm long rigid member which can slide on the flanges of the mould while holding the screed horizontal. The height of the screed shall be adjustable to give a uniformly flat surface finish to the mortar 7 mm ± 1 mm below the top of the mould.

(h) A metal tray with sides at least 3 mm high and an area equal to the surface area of the specimen.

(i) A hydrometer complying with BS 718.

(j) A float, 250 mm x 140 mm ± 5 mm.

(k) A medium soft 50 mm paint brush.

Procedure: preparation of specimens

16.1.4 The procedure for preparation of the specimens shall be as follows:

(a) Three pairs of specimens shall be prepared, each pair comprising one test specimen and one control specimen.

(b) Mixing shall be carried out in a room having a temperature of 27°C ± 3°C. The materials shall be brought to room temperature before mixing. A mortar mix shall be prepared comprising one part by mass of cement, three parts by mass of sand and 0.44 parts by mass of water.

(c) The sand and cement shall be placed in the mixer and mixed for 1 minute. The water shall be added and mixing continued for a further 4 minutes.

(d) The two moulds shall be cleaned, lightly coated with the petroleum jelly, mineral oil or release agent and weighed to the nearest 0.1 g (m_1).

(e) The specimens shall be prepared 20 minutes after completion of mixing and shall be cast in pairs.

(f) A layer of mortar approximately 25 mm deep shall be placed in each mould and tamped 50 times with the compacting bar. A second layer of mortar, sufficient to overfill the moulds slightly, shall be placed in each mould and tamped 50 times with the compacting bar. Indentations formed by tamping shall be filled and the surface shall be levelled by vigorous compaction by manual methods. Alternatively, each layer shall be compacted by using the vibrating table or vibrating hammer and levelled using the float.

(g) A uniform surface, free from undulations and surface defects, shall be produced using the minimum number of passes of the metal screed working along the length of the mould in both directions. The finished surface shall be 7 mm ± 1 mm below the top of the mould.

(h) The surface shall be brushed lightly with the paint brush to give an even texture.

(i) The moulds and specimens shall each be weighed to the nearest 0.1 g (m_2) immediately before the curing compound is applied.

Procedure: determination of efficiency index

16.1.5 The procedure for determination of the efficiency index shall be as follows:

(a) A sample of the curing compound shall be taken by the method for sampling admixtures in accordance with BS 5075: Part 1, Appendix A.

(b) The sample shall be agitated thoroughly and the relative density determined at room temperature with the hydrometer. The mass required to give the coverage rate stated in Clause 16.1.5(c) shall be calculated from the relative density. The mass of the curing compound applied shall be within ± 0.5 g of that required to give the specified coverage rate.

(c) The curing compound shall be applied at the coverage rate recommended by the manufacturer, or at a rate of 0.2 L/m^2 ± 0.01 L/m^2 if no rate is recommended.

(d) The curing compound shall be applied to the test specimen one hour after the specimen has been prepared, using the spray equipment or in accordance with the manufacturer's recommendations. The curing compound shall be shaken well before and during application. The spray gun shall be held so that the nozzle is as near vertical as possible and at a height which will result in uniform application and minimum overspray. The specimen shall be coated uniformly by applying several layers over the whole surface until the specified coverage is reached, checked by repeated weighing. Over spray shall be wiped from the exposed faces and edges of the mould. The whole application procedure shall be completed in not more than 2 minutes.

(e) The test specimen and the control specimen shall each be weighed to the nearest gram (m_3) and placed immediately on the lowest shelf of the cabinet. After the second pair of specimens has been prepared and weighed, the first pair shall be moved up one shelf and the second pair placed on the lowest shelf. After the third pair of specimens has been prepared and weighed, the first two pairs shall be moved up one shelf and the third pair placed on the lowest shelf.

(f) The total time for making the specimens, coating the test specimen and placing the pair in the cabinet shall not exceed 2 hours.

(g) The specimens shall be kept in the cabinet for 72 hours ± 15 minutes after application of the curing compound. Each specimen shall be weighed to the nearest 0.1 g at 24 hours ± 15 minutes and 48 hours ± 15 minutes. Each specimen shall be weighed to the nearest 0.1 g (m_4 and m_5) at 72 hours ± 15 minutes.

(h) The metal tray shall be weighed to the nearest 0.1 g (m_6) and coated with the same quantity ± 0.5 g of curing compound used on the test specimen. The coated tray shall be weighed to the nearest 0.1 g (m_7) and placed in the cabinet for 72 hours ± 15 minutes after application of the curing compound. The tray shall be removed from the cabinet and weighed to the nearest 0.1 g (m_8).

Calculation 16.1.6 (1) The proportion of solvent lost (V) by the curing compound during the test period shall be calculated from the equation:

$$V = \frac{(m_7 - m_8)}{(m_7 - m_6)}$$

where:

- m_6 is the mass of the tray (g)
- m_7 is the mass of the tray after coating (g)
- m_8 is the mass of the tray after 72 hours in the cabinet (g)

(2) The loss of water from the test specimen (W_t) and the loss of water from the control specimen (W_c) shall be calculated for each pair of specimens from the equation:

$$W_t = \frac{(m_3 - m_4) - V(m_3 - m_2)}{(m_2 - m_1)} \times 100\%$$

$$W_c = \frac{(m_2 - m_5)}{(m_2 - m_1)} \times 100\%$$

where:

- m_1 is the mass of the mould (g)
- m_2 is the mass of the mould and test or control specimen as appropriate (g)
- m_3 is the mass of the mould and test specimen after coating (g)
- m_4 is the mass of the mould and test specimen after 72 hours in the cabinet (g)
- m_5 is the mass of the mould and control specimen after 72 hours in the cabinet (g)

(3) The efficiently index (E') of the curing compound shall be calculated for each test specimen from the equation:

$$E' = \frac{(W_c - W_t)}{W_c} \times 100\%$$

The efficiency index (E) of the curing compound shall be calculated as the average of E' for the three test specimens.

Reporting of results 16.1.7 The following shall be reported:

(a) Details of the sample of curing compound including identification, source, size, date received and age at test.

(b) The method of compacting the mortar.

(c) The method of applying the curing compound and the type of spray gun used.

(d) The rate of application of the curing compound to the nearest 0.01 L/m^2.

(e) The duration of the test.

(f) The efficiency index of the curing compound to the nearest 0.1%.

(g) That the test method used was in accordance with this Specification.

APPENDIX 16.2

DETERMINATION OF THE DEFLECTION, RECOVERY AND RESISTANCE TO CRACKING OF PRECAST UNITS

Scope 16.2.1 This method covers the determination of the deflection and recovery of precast units, including prestressed units, and the resistance to cracking of prestressed units by means of a load test.

Equipment 16.2.2 The following equipment is required:

(a) Rigid supports.

(b) Test loads.

(c) Equipment for measuring the loads applied, readable and accurate to 2% of the specified test load.

(d) Equipment for measuring the deflection and recovery, readable and accurate to 0.5 mm.

Procedure 16.2.3 The procedure shall be as follows:

(a) The precast unit shall be supported at the specified points of support.

(b) The upward deflection at mid-span due to the prestressing force in a prestressed unit and the deflection at mid-span due to the self-weight of a non-prestressed unit shall be measured.

(c) The specified test load shall be applied at the specified loading points in not less than ten approximately equal increments.

(d) The specified test load shall be maintained for 5 minutes and removed in not less than five approximately equal decrements.

(e) The deflection at mid-span shall be measured for each load increment and each load decrement and 5 minutes after the loads have been removed.

(f) Steps (c) to (e) shall be repeated.

(g) Load-deflection graphs shall be plotted.

Reporting of results 16.2.4 The following shall be reported:

(a) Details of the precast unit, including place of manufacture.

(b) The age of the concrete in the precast unit at the time of the test.

(c) The loads applied to the nearest 2% of the specified test load.

(d) The deflections measured to the nearest 0.5 mm.

(e) The load-deflection graphs.

(f) Details of any cracks.

(g) That the test method used was in accordance with this Specification.

APPENDIX 16.3

DETERMINATION OF THE RECOVERY VALUE AND REDUCTION IN MASS, AND THE EXTRUSION OF JOINT FILLER

Scope 16.3.1 This method covers the determination of the recovery value and reduction in mass of joint filler by the compression and recovery test, and the extrusion of joint filler by the extrusion test.

Apparatus 16.3.2 The following apparatus is required:

(a) Equipment for measuring the plan dimensions of the joint filler, accurate to 0.5 mm.

(b) Equipment for measuring the thickness of the joint filler, accurate to 0.1 mm.

(c) A balance, accurate to 0.1% of the specimen mass.

(d) A compression test machine complying with BS 1610 with auxiliary platens 100 mm x 100 mm and a minimum thickness of 13 mm.

(e) An extrusion mould open on one side only and rigidly fixed to a base plate. The mould shall be 100 mm x 100 mm (+0.5 mm, -0 mm) internally and shall be of sufficient depth to test the specimen. The mould shall be provided with a close fitting pressure plate which shall fit without binding and with a horizontal measuring dial gauge or device readable and accurate to 0.1 mm.

Procedure: compression and recovery test 16.3.3 The procedure for determination of the recovery value and reduction in mass by the compression and recovery test shall be as follows:

(a) Four specimens from the sample shall be prepared, each 100 mm x 100 mm (± 2.5 mm).

(b) The thickness (t_1) of the four specimens shall be measured to the nearest 0.1 mm, and two specimens shall be weighed to within 0.1% of their mass (m_1).

(c) Each specimen shall be subjected to three applications of load in the compression test machine at 24 hour intervals. During each application of load the specimen shall be compressed to 50% of its original thickness at a rate of strain of 1.3 mm per minute. The load required to achieve the compression shall be at least 0.07 N/mm^2 and shall not exceed 10 N/mm^2. The load shall be released immediately the specified amount of compression is reached.

(d) After the third application of load, a recovery period of 30 minutes shall be allowed and the thickness (t_2) of each specimen shall be measured to the nearest 0.1 mm.

(e) The two previously weighed specimens shall be re-weighed to within 0.1% of their mass (m_2).

Procedure: extrusion test

16.3.4 The procedure for determination of the extrusion by the extrusion test shall be as follows:

(a) One 100 mm x 100 mm (± 0.5 mm) specimen shall be prepared.

(b) The thickness of the specimen shall be measured to the nearest 0.1 mm.

(c) The specimen shall be placed in the extrusion mould and subjected to one application of load as stated in Clause 16.3.3(c). The extrusion at the open side of the mould shall be measured to the nearest 0.1 mm with the gauge or device when the specimen is compressed to 50% of the original thickness and before the load is released.

Calculation

16.3.5 (1) The recovery value (R) of each specimen shall be calculated from the equation:

$$R = t_2/t_1 \times 100\ \%$$

where:

- t_1 is the original thickness of the specimen (mm)
- t_2 is the thickness of the specimen after the third application of load (mm)

(2) The reduction in mass (M) of each specimen shall be calculated from the equation:

$$M = (m_1 - m_2)/m_1 \times 100\ \%$$

where:

- m_1 is the original mass of the specimen (g)
- m_2 is the mass of the specimen after the third application of load (g)

Reporting of results

16.3.6 The following shall be reported:

(a) Type and source of filler.

(b) The recovery values to the nearest 0.5%.

(c) The reductions in mass to the nearest 0.1%.

(d) The extrusion to the nearest 0.1 mm.

(e) That the test methods used were in accordance with this Specification.

GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 17

PRESTRESSING

SECTION 17

PRESTRESSING

GENERAL

Materials for grout 17.01 Materials for grout for prestressing systems shall comply with Section 16 except as stated in this Section.

GLOSSARY OF TERMS

Duct 17.02 Duct is a void formed in the concrete to accommodate a prestressing tendon.

Prestressing components 17.03 Prestressing components are the components used in a prestressing system, including anchorages, grips, tendon deflectors, couplers, wedges, swages, nuts and other devices used to grip the prestressing tendon.

Prestressing tendon 17.04 Prestressing tendon is:

(a) an individual steel wire, wire strand or alloy steel bar in a duct, or

(b) an individual steel wire, wire strand or alloy steel bar not in a duct, or

(c) a group of steel wires or wire strands in a duct

used in a prestressing system.

Sheath 17.05 Sheath is a tube or lining which is used to form a duct and which is left in place.

MATERIALS

Prestressing tendons 17.06 (1) Prestressing tendons shall comply with the following:

High tensile steel wire and strand for the prestressing of concrete	: BS 5896
Hot rolled and processed high tensile alloy steel bars for the prestressing of concrete	: BS 4486.

(2) Steel wire and wire strand shall be in coils of sufficiently large diameter to ensure that the steel wire and wire strand will pay off straight.

(3) Alloy steel bars shall be straight.

Prestressing components 17.07 (1) Prestressing components shall be a proprietary type approved by the Engineer.

(2) Prestressing anchorages shall comply with BS 4447 and shall allow a minimum of 25 mm cover to cropped ends of prestressing tendons.

Sheaths 17.08 (1) Sheaths shall be a proprietary type approved by the Engineer and shall be steel or other material approved by the Engineer. Sheaths shall be rigid and strong enough to retain their shape during fixing and concreting and to withstand forces from the prestressing tendons without damage.

(2) The design of ducts shall allow for grout to be injected from either end. There shall be no sudden changes in the diameter of the duct.

Grout vents and taps 17.09 Taps for grout vents in ducts shall be a proprietary type approved by the Engineer and shall allow closure of the vents without loss of pressure in the duct. Vents to be used as grout entry points shall be threaded or fitted with screw connectors or other similar devices for connection to grout pumps.

Grout for prestressing systems 17.10 (1) Grout for prestressing systems shall consist of ordinary Portland cement and water. Sand, PFA and admixtures shall not be used unless permitted by the Engineer.

(2) Grout shall have a minimum crushing strength of 25 MPa at 7 days.

(3) The amount of bleeding of grout shall not exceed 2% in the first 3 hours and shall not exceed 4% in total; the water shall be reabsorbed by the grout during the 24 hours after mixing.

(4) Free expansion of grout shall not exceed 10% at the ambient temperature.

(5) The maximum total chloride content of grout, expressed as a percentage relationship between the chloride ion and the cementitious content by mass in the grout, shall not exceed 0.1%.

SUBMISSIONS

Particulars of prestressing systems 17.11 (1) The following particulars of the proposed prestressing systems shall be submitted to the Engineer:

(a) details of the prestressing system, including prestressing tendons, prestressing components, sheaths and tensioning apparatus,

(b) sequence of prestressing and ends of prestressing tendons from which prestress will be applied if not stated in the Contract,

(c) calculated values of:
- each type of loss of prestress
- prestressing tendon forces
- extensions of prestressing tendons and details of the method of measuring the extensions,

(d) a certificate showing that the tensioning apparatus has been tested and calibrated by an agent approved by the Engineer within a period of two years before the apparatus is to be used,

(e) any alterations to the reinforcement or additional reinforcement required to allow for primary bursting effects,

(f) details of corrosion protection required for the prestressing system, and

(g) details of the format of tensioning schedules and of reports of tensioning operations, grouting operations and testing of duct friction.

(2) Calculations for loss of prestress due to creep shall be based on the information stated in the Contract.

(3) The particulars shall be submitted to the Engineer for approval at least 8 weeks before the approval is required.

Particulars of prestressing tendons

17.12 (1) The following particulars of the proposed prestressing tendons shall be submitted to the Engineer:

- a certificate from the manufacturer showing the manufacturer's name, the date and place of manufacture and showing that the prestressing tendons comply with the requirements stated in the Contract and including details of:
  - cast analysis
  - diameter, cross-sectional area and unit mass
  - results of tests for mechanical properties, including the characteristic breaking load, characteristic 0.1% proof load, elongation at maximum load, relaxation and modulus of elasticity,
  - results of tests for ductility of prestressing wires.

(2) The particulars shall be submitted to the Engineer for each batch of prestressing tendons delivered to the Site and at least 28 days before installation of the prestressing tendons starts.

Particulars of grout mix and grouting procedure

17.13 (1) The following particulars of the proposed grout mix and grouting procedure for prestressing systems shall be submitted to the Engineer:

(a) water : cement ratio by mass,

(b) details of mixing and grouting equipment,

(c) method of quality control during grout injection, and

(d) details of grouting trials.

(2) The particulars shall be submitted to the Engineer at least 7 days before trial mixes for grout are made.

Samples of materials 17.14 Samples of the following proposed items shall be submitted to the Engineer at the same time as particulars of the prestressing systems are submitted:

(a) prestressing tendons,

(b) prestressing components,

(c) sheaths, and

(d) grout vents and taps.

TRIALS

Trial mixes for grout 17.15 (1) A trial mix for grout for prestressing systems shall be made to demonstrate that the proposed materials, grout mix and methods of production will produce grout which complies with the specified requirements.

(2) The trial mixes shall be completed at least 10 days before the grout mix is used in the permanent work.

(3) The Contractor shall inform the Engineer at least 24 hours, or such shorter period as may be agreed by the Engineer, before making trial mixes.

(4) Trial mixes shall be made using the materials, grout mix and methods of production submitted to the Engineer.

Samples: trial mixes for grout 17.16 (1) One sample of grout shall be provided from the trial mix to determine the amount of bleeding and free expansion of the grout. The method of sampling shall be as stated in Clause 17.59(2).

(2) One sample of grout shall be provided from the trial mix to determine the crushing strength of the grout. The method of sampling shall be as stated in Clause 17.62(2).

Testing: trial mixes for grout 17.17 (1) Each sample of grout taken as stated in Clause 17.16(1) shall be tested to determine the amount of bleeding and free expansion. The method of testing shall be as stated in Clause 17.60(2).

(2) Each sample of grout taken as stated in Clause 17.16(2) shall be tested to determine the crushing strength. The method of testing shall be as stated in Clause 17.63.

Non-compliance: trial mixes for grout 17.18 (1) If the result of any test for amount of bleeding, free expansion or crushing strength of trial mixes for grout does not comply with the specified requirements for the property, particulars of proposed changes to the materials, grout mix or methods of production shall be submitted to the Engineer. Further trial mixes shall be made until the result of every test complies with the specified requirements for the property.

(2) If grouting trials are carried out using the non-complying trial mix, further grouting trials shall be carried out unless in the opinion of the Engineer the changes to the materials, grout mix or methods of production will not affect the results of the previous grouting trials.

Grouting trials 17.19 (1) Grouting trials for grout for prestressing systems shall be carried out to demonstrate that the proposed materials, grout mix, methods of production and methods of construction will produce a grouted duct which complies with the specified requirements. The number and details of grouting trials shall be as stated in the Contract.

(2) Grouting trials shall be completed at least 3 days before grouting starts.

(3) The Contractor shall inform the Engineer 24 hours, or such shorter period agreed by the Engineer, before carrying out grouting trials.

(4) Grouting trials shall be carried out using the materials, grout mix, methods of production and methods of construction submitted to the Engineer.

(5) The profile of ducts and the method of support for grouting trials shall be as agreed by the Engineer. Vents shall be provided in ducts and tendons shall be pulled tight.

(6) Grouting trials which do not form part of the permanent work shall be removed.

Testing: grouting trials 17.20 Three sections selected by the Engineer shall be cut from the grouted duct and inspected not less than 2 hours after the grout used in the grouting trial has achieved its final set.

Compliance criteria: grouting trials 17.21 The sections of grouted duct cut in grouting trials shall be completely filled, and the prestressing tendon shall be completely surrounded with grout.

Non-compliance: grouting trials 17.22 If the result of any test on sections of grouted duct cut in grouting trials does not comply with the specified requirements for the test, or if in the opinion of the Engineer any aspect of the grouting procedure as demonstrated by the grouting trial is unsatisfactory, particulars of proposed changes to the materials, grout mix, methods of production or methods of construction shall be submitted to the Engineer; further grouting trials shall be carried out until the result of every test on sections of grouted duct complies with the specified requirements for the test and until in the opinion of the Engineer every aspect of the grouting procedure is satisfactory. Further trial mixes for grout shall be made unless in the opinion of the Engineer non-compliance of the grouting trial was not due to the grout mix.

Approved grout mix 17.23 A grout mix which complies with the specified requirements for trial mixes for grout and for grouting trials shall become an approved grout mix.

Commencement of grouting 17.24 Grouting shall not proceed until the grout mix has been approved by the Engineer.

Changes in materials and methods of construction 17.25 The materials, grout mix, methods of production or methods of construction used to produce an approved grout mix shall not be changed, unless permitted by the Engineer.

HANDLING AND STORAGE OF MATERIALS

Handling of prestressing tendons

17.26 Prestressing tendons shall not be subjected to rough handling, shock loading or dropping from a height.

Handling of prestressing components

17.27 Prestressing components shall be handled in accordance with the manufacturers' recommendations.

Storage of materials for prestressing systems

17.28 (1) Each prestressing tendon shall be tagged with a number to identify the coil or bundle number of the prestressing tendon used.

(2) Prestressing tendons and sheaths shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to the materials or in contamination of the materials.

(3) Different types and sizes of prestressing tendons, prestressing components and sheaths shall be stored separately.

(4) Prestressing tendons, prestressing components and sheaths shall not be stored on or adjacent to concrete surfaces which form part of the permanent work.

(5) Prestressing tendons, prestressing components and sheaths shall be protected from exposure to conditions which may affect the material.

SURFACE CONDITION OF MATERIALS FOR PRESTRESSING SYSTEMS

Surface condition of materials for prestressing systems

17.29 (1) Prestressing tendons, prestressing components and sheaths shall be clean at the time of installation and shall be free from loose mill scale, loose rust, pitting, grease or any substance which in the opinion of the Engineer is likely to reduce the bond or affect the prestressing tendons, prestressing components, sheaths, concrete or grout chemically; the prestressing tendons, prestressing components and sheaths shall be maintained in this condition until concrete or grout is placed around them.

(2) If the surface condition of the prestressing tendons, prestressing components or sheaths deteriorates such that it does not comply with the requirements stated in Clause 17.29(1), the prestressing tendons, prestressing components or sheaths shall be cleaned or dealt with by other methods agreed by the Engineer.

INSTALLATION OF PRESTRESSING SYSTEMS

Installation of prestressing systems

17.30 (1) Prestressing operations shall be carried out in such a manner that persons and property are not endangered by any sudden release of the energy stored in a stressed prestressing tendon.

(2) Prestressing tendons, prestressing components and sheaths shall be accurately located and maintained in the correct position during all operations; supports shall be placed at a maximum spacing of 600 mm.

Installation of prestressing tendons

17.31 (1) Prestressing tendons from each batch shall not be installed until testing of the batch has been completed.

(2) Steel wires, wire strands and alloy steel bars which will be tensioned in one operation shall be taken from the same batch.

(3) Individual steel wires and wire strands in the same duct shall not be twisted together. Strands which have become unravelled shall not be used.

(4) Unless permitted by the Engineer, alloy steel bars which have become bent shall not be straightened. Small adjustments for straightness may be made provided that the straightening is carried out at the ambient temperature by non-mechanical methods and provided that no force is applied on the threaded portion. Bars which have become bent in the threaded portion shall not be used.

(5) Prestressing tendons which have been damaged mechanically or by work-hardening or heating shall not be used. After manufacture, prestressing tendons shall not be welded and heat treatment, work-hardening, galvanizing and other metallic coatings shall not be applied.

Cutting prestressing tendons

17.32 Prestressing tendons shall be cut using either a high speed abrasive cutting wheel or a friction saw or by other methods agreed by the Engineer; flame cutting shall not be used.

Joints in prestressing tendons

17.33 Joints in prestressing tendons shall be made using couplers fixed in accordance with the manufacturer's recommendations.

Use of prestressing components

17.34 Prestressing components shall be used in accordance with the manufacturers' recommendations.

Installation of sheaths

17.35 At the time of tensioning, sheaths shall be free from dents or other irregularities which may affect tensioning.

Joints in sheaths

17.36 Joints in sheaths shall be securely taped to prevent penetration of the duct by concrete or grout. Joints in adjacent sheaths shall be staggered by at least 300 mm.

Installation of grout vents and taps

17.37 (1) Grout vents and taps shall be provided at the following positions:

(a) all crests of the prestressing tendon profile,

(b) all low points of the prestressing tendon profile,

(c) all anchorages, and

(d) intervals not exceeding 15 m.

(2) Vents shall not be placed at positions where they will be blocked by the prestressing tendons after tensioning.

TENSIONING OF PRESTRESSING TENDONS

Tensioning of prestressing tendons

17.38 (1) Apparatus for tensioning of prestressing tendons shall be a type such that a controlled total force is imposed gradually and such that excessive secondary stresses are not induced in the prestressing tendons and prestressing components or in the structure or element to which prestress is being applied.

(2) Prestressing tendons shall be securely attached to jacks and tensioning apparatus.

(3) Steel wires or wire strands which are tensioned simultaneously shall be approximately the same length between anchorage points.

(4) The force in the prestressing tendons during tensioning shall be measured by direct reading load cells or obtained indirectly from pressure gauges fitted in the hydraulic system. Load measuring devices shall be accurate to within 2%.

(5) The extension of prestressing tendons and any movement of prestressing tendons in the gripping devices shall be measured during tensioning. The elongation of prestressing tendons shall be measured to an accuracy of 2% or 2 mm, whichever is the more accurate.

(6) Tensioning apparatus and load measuring devices shall be calibrated before tensioning starts and at regular intervals agreed by the Engineer.

(7) The force in the prestressing tendons shall not be transferred to the concrete until the concrete has reached the specified transfer strength.

Pretensioning

17.39 (1) The stress in prestressing tendons shall be fully maintained during the period between pretensioning and transfer of stress. Transfer of stress shall take place gradually to minimise shock or damage to the transmission length and shall be carried out in conjunction with the release of any hold-down and hold-up forces in tendon deflectors.

(2) In the long-line method of pretensioning, locator plates shall be distributed throughout the length of the bed to ensure that the steel wires or wire strands are maintained in the correct positions during concreting. Units which are made in line shall be free to slide in the direction of their length to permit transfer of the prestressing force to the concrete along the whole line.

(3) Moulds used in the individual mould system of pretensioning shall be sufficiently rigid to provide the reaction to the prestressing force without excessive distortion.

(4) Tendon deflectors in contact with pretensioned prestressing tendons of single steel wire or wire strand shall have a radius of at least five times the prestressing tendon diameter for steel wire and at least ten times the prestressing tendon diameter for wire strand. The total angle of deflection shall not exceed 15^{o}. If a system is used such that friction develops between prestressing tendons and tendon deflectors, the friction force shall be determined by a test procedure agreed by the Engineer and any necessary allowance shall be made.

Post-tensioning

17.40 (1) A tensioning schedule shall be submitted to the Engineer for approval at least 48 hours before each post-tensioning operation starts. The schedule shall include the proposed sequence of tensioning the prestressing tendons, the required prestressing loads and the calculated extensions of the prestressing tendons.

(2) Spacers used with post-tensioned steel wire or wire strand which are not tensioned simultaneously shall be sufficiently rigid to ensure that they will not be displaced during successive tensioning operations.

(3) If both ends of the prestressing tendon are free to move, a demonstration shall be carried out before post-tensioning starts to show that all prestressing tendons are free to move in the ducts.

(4) Post-tensioning shall be carried out in such a manner that the stress in the prestressing tendons increases at a gradual and steady rate. The sequence of tensioning prestressing tendons and the ends of prestressing tendons from which prestress will be applied shall be as stated in the Contract or as approved by the Engineer.

(5) For each element of a structure being stressed, post-tensioning of the prestressing tendons shall be carried out until the required prestress to that element has been reached. Tensioning of each prestressing tendon shall be carried out continuously until the required tendon loads or extensions have been reached. If tensioning is stopped for more than 2 days, particulars of any proposals for remedial or other work shall be submitted to the Engineer for approval and tensioning shall not recommence until the approved work has been carried out.

(6) Measurement of extensions shall not commence until any slack in the prestressing tendon has been taken up. If the design permits, the draw-in of prestressing tendons at the non-jacking end shall also be measured. The tensioning shall be applied in increments of load and the extensions shall be measured at each increment. The average measured extension of the prestressing tendons shall be within 5% of the calculated extension and the measured extension of individual prestressing tendons shall be within 10% of the calculated extension.

(7) If the tendon deflector in contact with a post-tensioned prestressing tendon has a radius of less than 50 times the diameter of the prestressing tendon or if the total angle of deflection exceeds 15°, the loss of strength of the prestressing tendon shall be determined by a test procedure agreed by the Engineer and any necessary allowance shall be made.

(8) Post-tensioned prestressing tendons shall be cut at a distance from the anchorage of at least one diameter or 10 mm, whichever is greater. Unless otherwise permitted by the Engineer the tendons shall not be cut until at least 1 day after stressing, if the tendon is to be cut before grouting, or alternatively, at least 3 days after grouting.

Protection of external prestressing tendons and anchorages

17.41 External prestressing tendons and anchorages shall be protected in their permanent positions from mechanical damage or corrosion until the permanent protection is applied.

Records of tensioning operations

17.42 Records of tensioning operations shall be kept by the Contractor on the Site and a report shall be submitted to the Engineer within 24 hours of each tensioning operation. The report shall contain the following details:

(a) location of tensioning operations,

(b) coil, heat and bundle numbers of strand used,

(c) date and time of starting and completing tensioning operations,

(d) weather conditions,

(e) technical personnel supervising or carrying out tensioning operations,

(f) prestressing tendon reference numbers,

(g) tensioning apparatus identification,

(h) measured extensions,

(i) pressure gauge or load cell readings, and

(j) amount of draw-in.

INSPECTION OF PRESTRESSING SYSTEMS

Inspection of prestressing systems

17.43 The Contractor shall allow the Engineer to inspect the completed prestressing system before carrying out any work, including concreting and grouting, which will make access to the prestressing system difficult. The Contractor shall inform the Engineer 24 hours, or such shorter period agreed by the Engineer, before carrying out such work.

GROUTING OF PRESTRESSING SYSTEMS

Grouting equipment

17.44 (1) Grout for prestressing systems shall be mixed by a machine capable of producing a homogeneous colloidal grout and of keeping the grout in slow continuous agitation after mixing and until the grouting operation starts.

(2) Grouting equipment shall be capable of continuous operation with little variation of pressure and shall include a system of recirculating the grout when grouting is not in progress.

(3) Grout pumps shall be fitted with a safety valve to prevent the build-up of excessive pressure. The connection of the pump to the duct shall be by a screw connector or other positive method. Baffles to the pump shall be fitted with 1.18 mm sieve strainers; suction circuits shall be airtight.

(4) Grouting equipment shall be thoroughly washed through with clean water after every series of grouting operations and at the end of use each day.

Grouting effectiveness 17.45 Grouting of prestressing tendons shall be effective such that the duct is completely filled, and the prestressing tendon is completely surrounded, with grout.

Grout injection 17.46 (1) The permission of the Engineer shall be obtained before prestressing tendons are grouted. If grouting is not started within 24 hours of permission having been given, permission shall again be obtained from the Engineer.

(2) Grouting of prestressing tendons shall be carried out as soon as practicable, and not more than 5 days, after tensioning of the prestressing tendons.

(3) Immediately before grouting starts, the ducts shall be thoroughly washed by pumping clean water through the ducts. The water shall flow through all grout vents. Partial or complete blockage of grout vents shall be cleared before grouting starts. After washing, the ducts shall be blown dry with oil-free compressed air.

(4) Grout shall be used within 30 minutes of mixing unless a retarder is incorporated in the grout. If a retarder is used, the time shall be determined by a test procedure agreed by the Engineer.

(5) The grout pressure applied shall be as low as practicable and shall not exceed 1 MPa. Grout shall be injected from the lower end of ducts. Grout injection shall be continuous and steady and shall be at a rate which will avoid grout segregation and trapping air in the duct. Grout shall be allowed to flow from each of the grout vents until its consistency is equivalent to that of the grout injected. After the last grout vent has been closed, the pressure shall be maintained at 0.5 MPa for 5 minutes. The injection vent shall then be closed under pressure.

(6) If there is any blockage or breakdown or if the grout injection is interrupted, the duct shall immediately be thoroughly washed with clean water and blown dry with oil-free compressed air; regrouting shall start as soon as practicable.

(7) Grouted ducts shall not be subject to shock or vibration within 24 hours of grouting.

(8) The level of grout in grout vents shall be inspected and made good as agreed by the Engineer. Making good shall not be carried out until at least 2 days after grouting.

Records of grouting operations 17.47 Records of grouting operations for prestressing systems shall be kept by the Contractor on the Site and a report shall be submitted to the Engineer within 3 days of each grouting operation. The report shall contain the following details:

(a) location of grouting operations,

(b) date and time of starting and completing grouting operations,

(c) weather conditions,

(d) technical personnel supervising or carrying out grouting operations,

(e) prestressing tendon reference numbers,

(f) grout mix, including any admixtures,

(g) grout injection pressure,

(h) volume of grout used, and

(i) details of any interruptions and topping up.

TOLERANCES

Tolerances: sheaths 17.48 The line of sheaths shall be within 5 mm of the specified line.

TESTING: PRESTRESSED UNITS

Testing: prestressed units 17.49 Testing of prestressed units shall comply with Section 16.

TESTING: PRESTRESSING TENDONS

Batch: prestressing tendons 17.50 A batch of prestressing tendons is any quantity of prestressing tendons of the same type, size and grade, manufactured by the same manufacturer, covered by the same certificates and delivered to the Site at any one time.

Samples: prestressing tendons 17.51 (1) Samples of prestressing tendons shall be provided from each batch of prestressing tendons delivered to the Site and at least 28 days before installation of the prestressing tendons starts. The number of samples to be provided from each batch shall be as stated in Table 17.1.

(2) The number of specimens in each sample shall be 15.

(3) Each specimen shall be 1.5 metres long and straight.

(4) Each specimen shall be taken from different coils or bars in the batch. The ends of specimens shall be cut square without unravelling of wires before delivery to the laboratory.

Table 17.1: Rate of sampling prestressing tendons

Description	Size of batch	No. of samples per batch
Steel wire	0 - 50 tonnes	1
	exceeding 50 tonnes	1 for each 50 tonnes or part thereof
Wire strand and	0 - 100 tonnes	1

alloy steel bar	exceeding 100 tonnes	1 for each 100 tonnes or part thereof

Testing: prestressing tendons

17.52 (1) Each specimen of prestressing tendons shall be tested to determine the characteristic breaking load, characteristic 0.1% proof load, elongation at maximum load, diameter, cross-sectional area, unit mass and modulus of elasticity. Each specimen of prestressing wire shall also be tested to determine the ductility.

(2) Except that tests shall be carried out on specimens having a temperature of between 5°C and 30°C, the method of testing shall be in accordance with the following:

High tensile steel wire and strand for the prestressing of concrete	: BS 5896
Hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete	: BS 4486.

Compliance criteria: characteristic breaking load, characteristic 0.1% proof load

17.53 (1) The standard deviations of the results of tests for characteristic breaking load and characteristic 0.1% proof load, expressed as equivalent stress values, of prestressing tendons shall not exceed the following:

(a) tensile strength : 55 MPa

(b) 0.1% proof stress : 60 MPa.

(2) The statistical interpretation of the test results shall be in accordance with BS 2846: Part 3, Table 3 and BS 2846: Part 4, Table E, both for a one-sided tolerance interval of 0.95 and for a confidence level of 0.95.

Non-compliance: elongation, diameter, cross-sectional area, unit mass, modulus of elasticity, ductility

17.54 (1) If the result of any test for elongation at maximum load, diameter, cross-sectional area, unit mass, modulus of elasticity or ductility of prestressing tendons does not comply with the specified requirements for the property, one additional sample shall be provided from the same batch and additional tests for the property shall be carried out.

(2) The number of specimens in the additional sample shall be 15.

(3) The batch shall be considered as not complying with the specified requirements for the property if the result of any additional test does not comply with the specified requirements for the property.

TESTING: DUCT FRICTION

Testing: duct friction

17.55 (1) The number and details of tests to determine the duct friction in

prestressing systems shall be as stated in the Contract. The method of testing shall be as stated in Clause 17.55(2) to (4).

(2) Prestressing tendons shall be tensioned from one end and the tendon force shall be measured at both the jacking and non-jacking ends.

(3) The tendon force at the non-jacking end shall be measured by a load-measuring device of a type approved by the Engineer. A direct-reading load cell or a dummy jack is considered to be suitable as a load-measuring device. The load-measuring device shall be sufficiently rigid to ensure that the movement of the prestressing tendon at the non-jacking end under the specified tendon force is not excessive. The deflection of the load-measuring device shall be measured to an accuracy of 0.5 mm. A load-measuring device with a deflection exceeding 10 mm under the maximum load shall not be used.

(4) The prestressing tendon shall be tensioned to the specified tendon force in equal increments and the tendon extensions at the jacking end and the tendon force and tendon movement at the non-jacking end shall be measured to within 5 mm. The number of load increments shall be suited to the tensioning operation but shall be at least five.

Compliance criteria: duct friction 17.56 The force at the non-jacking end of the prestressing tendon determined in the duct friction test shall be within +10% and -5% of the calculated value.

Records of duct friction tests 17.57 Reports of duct friction tests shall be submitted to the Engineer within 3 days of each test. The report shall contain the following details:

(a) details stated in Clause 1.42(1),

(b) prestressing tendon reference numbers,

(c) graph showing tendon forces at jacking end against tendon forces at non-jacking end, and

(d) comparison between the calculated tendon forces at the non-jacking end and the measured values.

TESTING: GROUT - GENERAL REQUIREMENTS

Batch: grout for prestressing systems 17.58 A batch of grout for prestressing systems is any quantity of grout produced in one cycle of operations of a mixer.

TESTING: GROUT - BLEEDING AND FREE EXPANSION

Samples: bleeding and free expansion of grout 17.59 (1) For each grout mix one sample of grout shall be provided from each 25 batches of grout, or from the amount of grout produced in a day, whichever is the lesser, to determine the amount of bleeding and free expansion of the grout.

(2) Samples shall be provided and testing commenced within 1 hour after the grout has been mixed. Samples shall be protected from rain before the tests for amount of bleeding and free expansion are carried out.

Testing: bleeding and free expansion of grout

17.60 (1) Each sample of grout taken as stated in Clause 17.59 shall be divided into three specimens; each specimen shall be tested to determine the amount of bleeding and free expansion.

(2) A portion of each specimen shall be placed in a covered cylinder with a diameter of 100±10 mm, to a depth of 100±5 mm and the amount of bleeding and free expansion measured by a scale fixed to the outside of the cylinder.

Non-compliance: bleeding and free expansion of grout

17.61 If the result of any test for amount of bleeding or free expansion of grout for prestressing systems does not comply with the specified requirements for the property, particulars of proposed changes to the materials, grout mix or methods of production shall be submitted to the Engineer; further trial mixes shall be made and further grouting trials shall be carried out unless otherwise permitted by the Engineer.

TESTING: GROUT - CRUSHING STRENGTH

Samples: crushing strength of grout

17.62 (1) For each grout mix one sample of grout shall be provided from each 25 batches of grout, or from the amount of grout produced in a day, whichever is the lesser, to determine the crushing strength of the grout.

(2) Samples shall be provided not more than 1 hour after the grout has been mixed and shall be protected from rain before test cubes are made.

Testing: crushing strength of grout

17.63 (1) Two 100 mm test cubes shall be made from each sample of grout taken as stated in Clause 17.62. Each pair of test cubes shall be tested to determine the crushing strength at 7 days.

(2) The method of making, curing and testing the test cubes, and the calculation of the test results, shall be as stated in Clause 16.59(2), (3), (4) and (5), except that compaction of the grout is not required.

Non-compliance: crushing strength of grout

17.64 If the result of any test for crushing strength of grout for prestressing systems does not comply with the specified requirements for crushing strength, particulars of proposed changes to the materials, grout mix or methods of production shall be submitted to the Engineer; further trial mixes shall be made and further grouting trials shall be carried out unless otherwise permitted by the Engineer.
