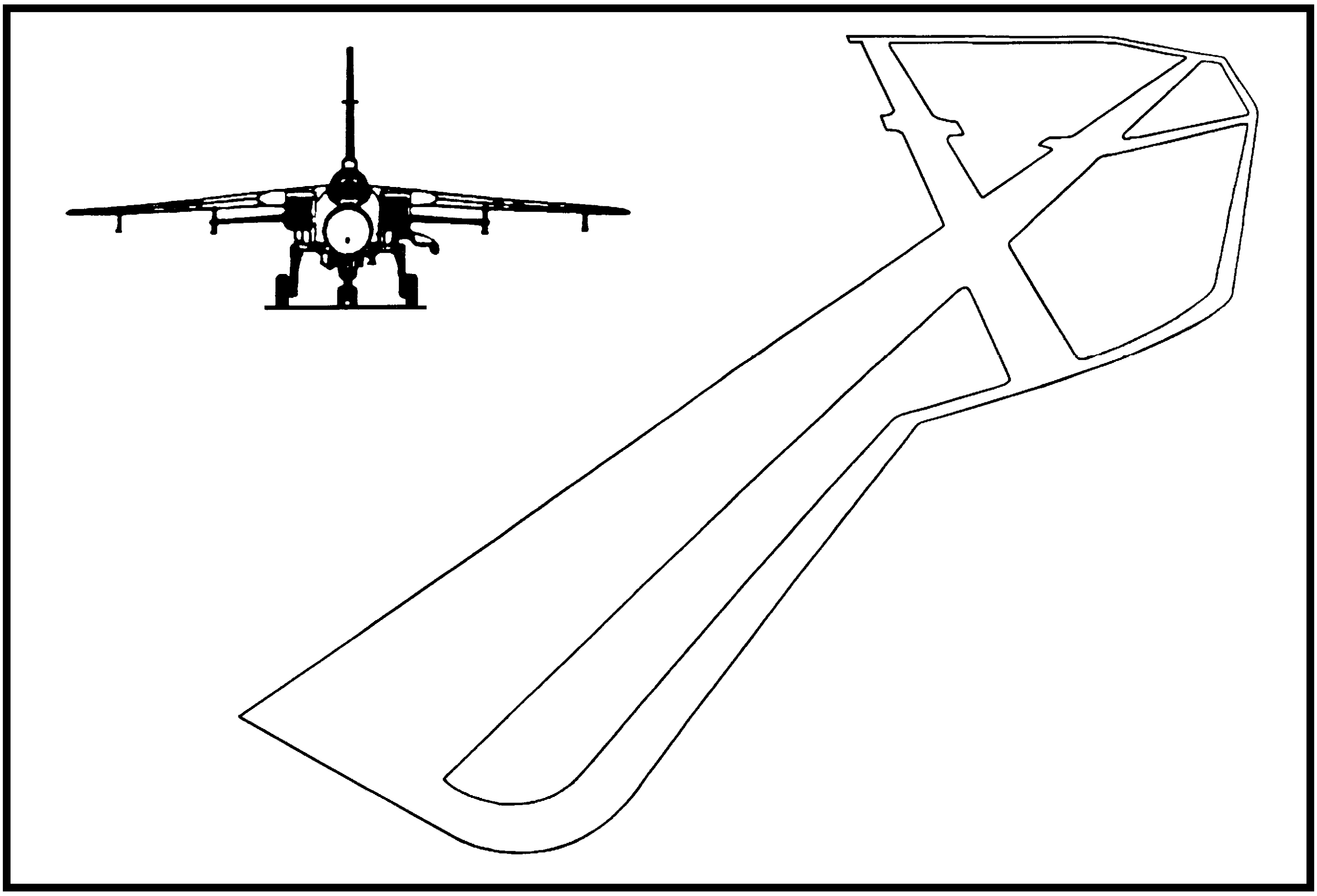
Specification 033



Pavement Quality Concrete for Airfields

DEFENCE INFRASTRUCTURE ORGANISATION
MINISTRY OF DEFENCE

Specification 033

Pavement Quality Concrete for Airfields

February 2017

AIRFIELD PAVEMENT TEAM
DEFENCE INFRASTRUCTURE ORGANISATION

Ministry of Defence

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Foreword

This document is for the use of Top Level Budget Holders (TLBHs) for application by the Project Sponsors and their Project Managers, Property Managers (PROM), Establishment Works Consultants (EWC), Works Service Managers (WSM) and other parties involved with airfield pavement works.

This Defence Infrastructure Organisation Specification supersedes the previous edition published in April 2005.

This Specification was prepared under the patronage of the Airfield Pavements Team, Defence Infrastructure Organisation, Ministry of Defence, for application to airfield pavement works on the MOD estate. It was prepared following detailed contributions from members of the Britpave Heavy Duty Pavements Working Group and other industry personnel

The application and limitations of the specification requirements in this DIO Specification are outlined in Section 1. Further technical assistance regarding the contents of this document can be obtained from DIO. Approaches may be made through local DIO offices or directly to the airfield pavement Technical Works Authority (DE TA):

Head of Airfield Pavements
Safety, Environmental &Engineering (Engineering & Construction)
Defence Infrastructure Organisation
Kingston Road
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This Specification "Pavement Quality Concrete for Airfields" has been devised for use of the Crown and of its Contractors in the execution of contracts for the Crown and, subject to the Unfair Contracts Terms Act 1977, the Crown will not be liable in any way whatever (including but without limitation negligence on the part of the Crown, its servants or agents) where the specification is used for other purposes.

Glossary of Technical Terms

Added Filler	Filler aggregate that is additional to that inherent in the course and fine aggregate
Addition	Finely divided inorganic constituent used in concrete in order to improve certain properties or to achieve specific properties
Aggregate / Cement Ratio	The ratio between the total mass of aggregate, including the mass of any absorbed water, in a concrete mix and the mass of cement in the mix.
Asphalt	A mixture of coarse and fine aggregate, filler aggregate and bituminous binder used in the construction of flexible pavements for roads and airfields.
Asphalt Concrete	An asphalt mixture consisting of continuous graded aggregate, filler aggregate and bituminous binder proportioned to produce a dense and impermeable surfacing.
Asphalt Surfacing	A porous friction course, surface course, or a combination of these, and a binder course.
Asphaltic Concrete	Alternative name for ‘Asphalt Concrete’.
Base	Structural layer(s) of a pavement immediately below the Binder Course that are bound.
Basecourse	Previous name for ‘Binder Course’.
Bay (of Concrete)	The area of slab bounded by adjacent pairs of longitudinal and transverse joints or grooves.

Bay Layout	The pattern of joints and grooves on a concrete pavement.
Béton Bitumineux pour chaussées Aéronautiques (BBA)	Asphalt concrete mix design for airfield pavements that was developed in France.
Binder	A material used for the purpose of holding solid particles together as a coherent mass.
Binder Course	The layer or layers of the asphalt surfacing immediately below the surface course. (Previously called 'Basecourse').
Bitumen	Binder obtained from crude oil by refinery processes.
Bitumen Emulsion	An emulsion in which bitumen is dispersed in water or in aqueous solution with the aid of suitable emulsifying agents.
Bitumen Macadam	See 'Macadam'.
Bituminous	Containing bitumen. (Previously included road tar, pitch or mixtures thereof).
Bituminous Surfacing	Alternative name for 'Asphalt Surfacing'.
Bond Coat	.Proprietary bitumen spray that provides additional adhesion and imperviousness to that achieved with a Tack Coat and, therefore, improved bond between layers when applied at the rate of application recommended by the manufacturer for the particular situation
Cement	Finely ground inorganic material which when mixed with water forms a paste which sets and hardens by means of hydration reactions and processes and which after hardening retains its strength and atability even under water
Coarse Aggregate	For asphalt, aggregate mainly retained on a 2.0 mm test sieve and containing no more finer material than is permitted for the various sizes in BS EN 13043. For concrete and block making, aggregate mainly retained on a 4.0 mm test sieve and containing no more finer material than is permitted for the various sizes in BS EN 12620.

Cold Recycled Bound Material (CRBM)	A material produced ex situ in a fixed or mobile mixing plant from recycling base and binder courses from existing pavements. The recycling process allows for the crushing, screening and grading of excavated material, blended if necessary with other aggregate, and bound with bituminous and hydraulic binder(s) including cement.
Combination	Restricted range of Portland cements and additions which, having been combined in the concrete mixer, count fully towards the cement content and water/cement ratio in concrete
Construction Joint	A joint separating areas of a concrete pavement slab placed during different pours, usually on different days. May be a longitudinal, or lane, joint or a transverse joint across a lane.
Contraction Groove	A groove formed in the surface of a concrete slab, either during or soon after laying, in order to induce shrinkage cracking to occur in a controlled manner. Usually formed transversely at regular intervals along a lane of concrete by saw cutting so as to subdivide it into approximately square bays.
Crushed Aggregate	Aggregate produced by crushing rock or gravel.
Cutback Bitumen	Bitumen whose viscosity has been reduced by the addition of a suitable volatile diluent.
Dense Bitumen Macadam (DBM)	See 'Macadam'.
Drylean concrete	A cement bound granular material with low water content suitable for use as a Base or subbase. Unlike conventional concrete, it is usually compacted by rolling.
Edge Restraint	Device that serves to prevent sideways movement of paving units and prevents loss of material from the laying course, base or subbase.
Expansion Joint	Joint provided in a concrete pavement to accommodate the expansion which occurs when the temperature of the pavement rises.
Enrobé à Module Élevé Class 2 (EME2)	High modulus bituminous mixture that was developed in France.

Filler Aggregate	For asphalt, aggregate, most of which passes a 0.063 mm sieve as permitted in BS EN 13043, which can be added to construction materials to provide certain properties. For concrete and block making, aggregate, most of which passes a 0.063 mm sieve as permitted in BS EN 12620, which can be added to construction materials to provide certain properties.
Fine Aggregate	For asphalt, aggregate mainly passing a 2.0 mm test sieve and containing no more coarse material than is permitted for the various gradings in BS EN 13043. For concrete and block making, aggregate mainly passing a 4.0 mm test sieve and containing no more coarser material than is permitted for the various gradings in BS EN 12620.
Fines	Any solid material passing a 0.063 mm test sieve.
Fly ash Bound Material (FABM)	A hydraulically bound mixture in which siliceous or calcareous fly ash is the essential constituent of the binder. (NOTE: siliceous fly ash used in the specification.)
Foreign Object Damage (FOD)	Damage sustained by aircraft as a result of foreign objects striking the aircraft or being ingested into jet engines. Potential sources of damage are generally referred to as FOD hazards.
Free Water/Cement Ratio	The ratio between the mass of water, less any water absorbed by the aggregates, in a concrete mixture and the mass of cement in the mixture.
Friction Course	See ‘Porous Friction Course’.
Grading	Particle size distribution of an aggregate.
Heavy Duty Macadam (HDM)	See ‘Macadam’.
Hot Rolled Asphalt (HRA)	An asphalt mixture of gap-graded aggregate, filler aggregate and bitumen binder proportioned to a design or recipe to produce a dense and impermeable surfacing material.
Hydraulically Bound Mixture	A mixture which sets and hardens by hydraulic reaction. It is compacted by rolling and is suitable for use as a base or sub-base.

Hydraulic road binders (HRB)	Hydraulic road binders are proprietary binders which are a powder made from a blend of different constituents.
Interlock	Effect of frictional forces between concrete blocks that prevent them moving vertically in relation to each other.
Intermediate Restraint	Device that is used to provide restraint of concrete block paving units at intervals in the paved surface.
Joint Filling Material	Material used to fill the joints between concrete blocks. Often referred to as 'joint filling sand'.
Joint Width	The distance between adjacent concrete blocks or concrete blocks and restraint.
Laitance	On a concrete pavement, a thin layer with poor durability formed of fine aggregate, cement and water brought to the surface, usually by overworking.
Lane	A longitudinal strip of a pavement layer produced by one pass of a set of paving equipment.
Lane Joint	A construction joint between adjacent lanes.
Laying Course Material	Layer of material on which concrete blocks are bedded. Often referred to as the 'bedding sand' or 'laying course sand'.
Laying Face	Working edge of the wearing surface when concrete blocks are being laid out.
Laying Pattern	An arrangement of concrete blocks to form specific patterns for structural requirements.

Macadam	An asphalt mixture (nominally an Asphalt Concrete) consisting of graded aggregate coated with bitumen. a. Dense Bitumen Macadam (DBM): A dense, relatively impermeable, Macadam coated with a bitumen binder and with a filler aggregate content of between 2% and 9%. b. Heavy Duty Macadam (HDM): A dense bitumen Macadam with 40/60 pen grade bitumen binder and a high filler aggregate content of 7% to 11%. c. Pervious Macadam: A layer of 0/32 mm Porous Asphalt which acts as a topping to protect whilst allowing free penetration of the surface water to French drains.
Marshall Asphalt	An Asphalt Concrete designed to achieve specified stability, flow, voids and density characteristics.
Optimum Moisture Content	The moisture content at which maximum compaction is achieved.
Particle Size Fraction	That portion of aggregate which passes one sieve but is retained on the adjacent smaller sized sieve in the sequence of sieves used to specify that grading.
Pavement	A structure consisting of a layer or superimposed layers of selected materials, whose primary purpose is to distribute the applied load to the Subgrade.
Pavement Quality Concrete (PQC)	A cement concrete of a suitable quality for use as the surfacing on airfield pavements.
Pervious Macadam	See ‘Macadam’.
Petroleum Bitumen	See ‘Bitumen’.
Porous Asphalt	An asphalt mixture consisting of gap-graded aggregate and binder with a relatively open structure that is pervious to air and water.
Porous Friction Course	A relatively thin layer of 2/10 mm aggregate sized Porous Asphalt that allows free penetration of the surface water to the underlying impervious surface course.
Quick Visco-Elastic (QVE)	Type of CRBM in which the primary binder is bitumen but also includes a proportion of Portland Cement.

Ramp	A section of pavement, usually laid at a gradient near the maximum permissible, which accommodates differences in level between adjacent pavements. (Note that, in US terminology, 'Ramp' may also be used to indicate an aircraft parking area).
Regulating Material	Asphalt of variable thickness applied to an existing pavement to adjust the shape preparatory to resurfacing.
Road Tar	A viscous liquid derived from crude tar obtained by the destructive distillation of coal which was, but is no longer, used as a component in asphalt.
Roadbase	Previous name for 'Base'.
Sand (for making concrete)	Now called 'Fine Aggregate'.
Sieved Fraction	Previous name for 'Particle Size Fraction'.
Slag Bound Material(SBM)	A mixture containing one or more slags which hardens by hydraulic reaction and/or carbonation.
Stone Mastic Asphalt (SMA)	A dense gap-graded asphalt with aggregate-to-aggregate interlock that includes fibres as a stabilising additive to carry the binder without drainage.
Subgrade	Upper part of the soil, natural or constructed, that supports the loads transmitted by the overlying pavement.
Surface Course	The layer of the asphalt surfacing immediately below the porous friction course or which directly supports the traffic. (Previously called 'Wearing Course').
Tack Coat	A thin film of bitumen emulsion to improve the adhesion between two courses of asphalt or between an existing surface and a new asphalt layer.
Thin (Asphalt) Surfacing System	A proprietary asphalt product with suitable properties to provide a surface course that is laid at a nominal depth of less than 50 mm (previously limited to 40 mm).
Uncrushed Aggregate	Aggregate resulting from the natural disintegration of rock.
Wearing Course	Previous name for 'Surface Course'.

(NOTE. This glossary is common to all DIO Specifications for asphalt, block paving and concrete pavement materials and the Project Manager should delete any terms not applicable to a particular project and should add any terms necessary due to the particular nature of that project.)

Contents

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1 Introduction

1.1 BACKGROUND

1.1.1 The unique characteristics of military aircraft, in terms of speed, weight, tyre pressures, etc., demand specialist requirements in the surfacing of MOD airfields. The specifications for materials and workmanship need to be particularly stringent to meet these requirements.

1.1.2 This Standard for Pavement Quality Concrete (PQC) is one of a series being produced by Defence Infrastructure Organisation (DIO) to lay down specification requirements for airfield pavement works. The following clauses in this Section are intended to set out the applications of PQC in the construction and refurbishment of MOD airfield pavements.

1.1.3 The use of this Standard does not absolve a Project Manager from any responsibility for the designs; neither does it constrain the Project Manager from using alternatives, provided such alternatives can be demonstrated to provide a result of equal quality.

1.2 FUNCTIONAL REQUIREMENTS OF AIRFIELD PAVEMENTS

The pavements must facilitate safe aircraft ground operations. In order to do this they must meet certain specialist performance requirements. The following sets out the main requirements, the relative importance of which will be dependent on the function of the pavements and the nature and type of aircraft operations:

- Good rideability.
- Good friction and drainage characteristics.
- High strengths and stability to withstand the shear stresses induced by heavy wheel loads and high tyre pressures.
- A durable, hard-wearing, weatherproof surface free from loose material and sharp edges which might endanger aircraft.
- Resistance to fuel spillage and jet blast. Depending on the nature and type of aircraft operations, these requirements are likely to be too onerous for bituminous surfacings in certain areas of the airfield.
- Facilitate economic maintenance.

1.3 USE OF PAVEMENT QUALITY CONCRETE

1.3.1 General

The use of PQC either for new pavements or for refurbishment of existing ones is dependent on the functional requirement of the pavement and cost. In the case of refurbishment work, the provision of an asphalt overlay will often be a more attractive option in terms of cost and construction time with re-construction or over slabbing in PQC being reserved for those pavement areas subject to the most severe service conditions. The following gives some additional considerations on the use of PQC in relation to the principal pavement areas on an airfield.

1.3.2 Main Length of Runway

It is important on the main length of a runway to have good rideability and wet weather skid resistance. Bituminous surfacings generally give better rideability than PQC. Good skid resistance/friction characteristics are achieved by a combination of good surface shape to effect efficient surface water run-off and also surface texture to increase friction and allow water to disperse from under the tyre contact area. To meet these requirements the most favoured option for MOD runways in the UK is the provision of a 20 or 25 mm thick Friction Course on Marshall asphalt surfacing; separate DIO Functional Standards give details of these materials. For runways used for Short Take off and Landing (STOL) operations by aircraft with thrust vectoring capability, it may be necessary to provide a PQC main runway length. Further advice on a project/works specific basis can be obtained from the Airfield Pavements Team, DIO.

1.3.3 Runway Ends and Adjoining Aircraft Holding Areas.

Service conditions can be severe in these areas where jet blast and fuel spillage are likely to be most damaging and aircraft carry out sharp turns. The material most frequently used on runway ends and holding areas at MOD airfields is PQC. However, with certain aircraft, the effect of jet blast on the pavement surface is not critical (e.g. piston-engined aircraft, turboprops or turbojets where the jet exhaust is located at a safe height above the pavement). In these instances asphalt provided with a fuel resistant surface treatment or alternatively incorporating a fuel resistant binder is likely to be a viable and economic alternative to PQC. Possible future change of aircraft type or use by visiting or temporarily based aircraft of other types need to be considered when making the decision.

1.3.4 Taxiways

Friction characteristics and rideability are not as critical as for the main length of a runway. Fuel spillage and jet blast are not normally critical considerations in these areas and therefore the use of PQC will largely be dependent on cost relative to other suitable materials.

1.3.5 Parking and Servicing Aprons

PQC is very much the preferred construction option for these areas on MOD airfields because of its resistance to jet blast and fuel spillage, to indentation from parked aircraft having very high tyre pressures and to a measure of impact from ground equipment. Alternative materials have been used on MOD hardstandings mainly to rehabilitate old PQC at relatively low cost when it has still been structurally sound. These alternatives have included asphalt, usually provided with either a fuel resistant surface treatment or incorporating a fuel resistant binder, concrete block paving and grouted macadam. The performance and thereby cost effectiveness of these materials is dependent on the use of the hardstanding including type of aircraft, frequency of use, tyre pressures and use of ground equipment. Separate DIO Specifications give details on Marshall Asphalt, Hot Rolled Asphalt and Macadams, Concrete Block Paving, Porous Friction Course and Stone Mastic Asphalt for Airfields.

1.4 APPLICATION AND LIMITATIONS OF THIS STANDARD

1.4.1 Design of Rigid Pavements

Specification Clauses in this Standard are consistent with the preferred form of rigid construction in the DIO reference document for the design of airfield pavements (A Guide to Airfield Pavement Design and Evaluation – Defence Estates 3rd Edition February 2011). The relevant factors are as follows:

- For new rigid pavements the standard practice on MOD airfields is to provide a drylean concrete base. The purpose of this is to provide a uniform and improved support to the PQC and help preserve aggregate interlock at transverse joints (and thereby load transfer) and also to provide a level and firm working course on which to lay the PQC.
- The Specification does not include for the provision of traditional load transfer devices such as dowels or keys because it is not standard practice to provide them in PQC on MOD airfields. In certain circumstances, however, their provision may be an essential element of a cost effective design. Such circumstances might include climates with very high seasonal variations in temperature or where heavy trafficking by aircraft occurs normal to the longitudinal joints (i.e. plain butt construction joints providing little or no load transfer). The reference document for the design of airfield pavements gives details on the provision of dowel bars.
- The spacing and layout of joints in the Specification complies with the requirements in the Design Guide reference document. For climates with very high seasonal variations in temperature the spacing of expansion joints may need to be modified; the Design Guide reference document gives details.
- The Specification does not include for the provision of reinforcement or dowelled joints in PQC. This is because previous experience on MOD airfields has indicated that reinforced PQC as a 'surface' material is more likely to present long term maintenance problems than the standard undowelled, unreinforced PQC. It is not therefore standard practice to provide reinforced PQC.

1.4.2 Climate

For laying PQC in hot climates some modifications to the Specification are likely to be required, e.g. the time allowed for concreting from the addition of water to the concrete mix to the finishing of the slab may need to be reduced and the curing provision may need to be enhanced.

1.4.3 Vertical Take Off and Landing (VTOL) Pads, Engine Running Platforms (ERPs) and Short Take Off and Landing (STOL) Runways/Strips

VTOL pads for Harrier operations and ERPs for high performance jet aircraft have previously provided the most severe conditions for pavements on MOD airfields. PQC is normally provided in these areas. Its life-span is dependent on frequency and mode of usage but currently the average life-span is 10 years. This compares with an average life-span in excess of 30 years for PQC in other areas of an airfield. Special requirements for PQC for VTOL pads will apply in respect of joint details and joint sealants.

Consideration should be given to the use of PQC for STOL runways/strips that are to be used by aircraft with thrust vectoring capability. Further advice is also available concerning PQC pavements subject to the higher temperature efflux from later aircraft. e.g. For VTOL pads for Lightning II heat resistant concrete specifications have been developed.

1.4.4 For Works of Small Scope

For small scopes of work it may be necessary to modify the Specification in order to achieve a realistic balance between cost and quality requirements. Such considerations may apply to aggregate types and test requirements and the provision of a dedicated on-site concrete mixing plant. Cubes may be used for compliance in accordance with BS EN 13877-1 with the approval of the Project Manager. Some guidance is given at Appendix Z.

1.4.5 For Works in Remote/Overseas Locations

Similar considerations apply as described for works of small scope in Clause 1.4.4.

1.4.6 For Works with Short Closure Times

Where closure times are short Rapid Hardening Concrete (RHC) can provide adequate compressive strengths within as little as 2 to 3 hours. It can be used on runways, taxiways and hard standings and typically lends itself to solutions where strips of concrete are needed mainly during overnight possessions. The DIO Airfield Team should be consulted on proposals of this nature because RHC is not covered in this specification, however RHC has been used at civil airports to good effect.

1.4.7 Other Concretes and Constituents

DIO Airfield Pavements team may be consulted for advice regarding suitability of microsilicates, fibres (either steel or synthetic). Fibres are not included within this Airfields specification, however guidance may be sought on their application for other non critical locations.

1.5 SPECIFICATION CLAUSES FOR PAVEMENT QUALITY CONCRETE

Specification clauses are contained in Sections 2 to 8 and Appendices A to C of this Standard. Guidance Notes for the Project Manager on Quality Systems are given in Appendix Y and for the Preparation of Job Specifications in Appendix Z.

1.6 ADVICE FROM AIRFIELD PAVEMENTS TEAM, DIO

Clauses 1.2, 1.3 and 1.4 provide general advice on the application of this Standard. However, having regard to the various design parameters affecting the choice of construction and specifications, including scope of work, aircraft type and frequency of usage, location of a pavement on an airfield, design life, timescale constraints and existing pavement constructions, the guidance notes cannot be exhaustive. Further advice on a project/works specific basis can be obtained from the Airfield Pavements Team, DIO.

1.7 ENHANCEMENTS FROM THE 2005 VERSION OF THIS SPECIFICATION

This Specification encompasses the currently available European standards for concrete, aggregates and concrete pavements. The main changes and expectations are:

i. Cements to BS EN 197-1:2011 may be (CEMI, CEMII/A-S, CEMII/B-S, CEMII/A-V & CEMIIB-V) or Combination to BS8500 may be of CEM I to BS EN 197-1:2011 with BS EN 15167-1:2006 or BS EN 450-1:2012 (CIIA-S, CIIB-S, CIIA-V & CIIB-V).

ii. Additions may be used but only up to the limits of 25% for fly ash and 35% for ggbs. This broadly aligns with Highways England (HE) guidance and also reflects feedback from past DIO usage and industry experiences derived from pavement works carried out on UK civil airports

iii. Onsite batching of combinations with CEMI is the expected model.

iv. Concrete strength grade designations are to 28 day compressive strengths

v. Flexural strength for F5 F5.5 and F6 concrete is introduced. For these concretes the relationships between compressive strengths from cores, cubes and flexural beam tests is to be established in the laboratory, by way of the trials and by testing as the permanent works proceed.

vi. For concrete flexural strength 4.5, 4.0 and 3.5 N/mm^2 made with CEMI, DIO retains all those concrete compressive strength values which appeared in the 2005 Specification. These values continue to appear in the respective sections throughout this specification. (A listing is provided at Table Z.2 of this Appendix).

vii. Flexural strength beam tests are to be undertaken for the F4.5, F4.0 &F3.5 concrete. This extension of beam testing for F4.5 and below is for research purposes and allows DIO, in liaison with industry, to establish relationships between cube, core, and flexural strengths and to relate these to the higher F5 to F6 strengths .
[Notes:
1. Routine flexural strength beam testing is already undertaken by industry. Summary test information regarding beams, cores and cubes is to be sent to DIO Airfield Pavements Section for collation
2. Clause 4.6.1 and Appendix Z provide further guidance on the values contained in the respective sections of this specification]

viii. The magnesium sulphate testing requirements align to BSEN1367-2 : 2009 for all fractions. Appendix A is retained within this specification to ensure that all fractions are tested.

ix. The requirement for air entrainment is retained and the plus limit is now amended.

x. A water absorption testing requirement is introduced with a 2% limit

xi. The coarse aggregate supplied to be in two sizes 4/10 and 10/20, with 20/40 as an option should that be required for non UK locations

xii. The coarse aggregate requirement continues to be crushed limestone. The precautions against alkali-silica reaction are now aligned with BS8500-2 Annex B. The Appendix Z Guidance Notes provide information drawn from relevant parts of BS 8500:2015. The requirement includes a full review of sources of fine aggregate. The contribution from all constituents is to be supported by calculation to avoid the possibility of ASR developing. A 3.25kg/m3 alkali limit now replaces the previous 3kg/m3 limit.

xiii. Chloride testing of aggregates is required at least once per production week to ensure that the limits used for ASR are not exceeded.

xiv. The joint details have been revised, including a construction joint using a 5mm 45 degree chamfer as an alternative to a bull nosed arris.

xv. A core density requirement is introduced

xvi. For compaction testing flexibility is now introduced whereby the Compacting Factor test may be used instead of, or as well as, the Compactability (Compaction Index) test

1.8 PRINCIPLES RETAINED FROM THE 2005 VERSION OF THIS SPECIFICATION

i. A requirement that cores are to be cut from the finished pavement for compliance purposes. Each core can be used for determination of pavement depth, density and strength. For quality control purposes cubes will be used as previously described

ii. A corrected core strength is required as opposed to an estimated in-situ cube strength, however, cubes may be used as detailed in Clause 4.6. (and the cubes may be 100 mm for 20 mm aggregate)

iii. Cores to be taken from the pavement at an age of 3 – 7 days.

iv. The volumetric patch test is used instead of sand patch test for determining texture depth and this requires the use of solid glass spheres.

2 General

2.1 REFERENCES

All references to British Standards and other documents given in this Specification refer to the editions as listed in the References at the end of this document unless otherwise stated.

2.2 OVERALL REQUIREMENTS

Pavement Quality Concrete shall be specified, mixed and laid to the requirements of the following clauses in this Specification. The requirements of this Specification are arranged in the following parts:

General	Section 2
Constituent Materials	Section 3
Design and Composition	Section 4
Plant, Workmanship and Production Testing	Section 5
Trials	Section 6
Concrete for Surface Surrounds to Fittings	Section 7
Summary of Tests	Section 8
Magnesium Sulphate Soundness Test	Appendix A
Straightedge Tests	Appendix B
Tests for Manufactured Joint Fillers	Appendix C

2.3 USE OF PAVEMENT QUALITY CONCRETE

Pavement Quality Concrete shall be used in the locations indicated on the Project drawings.

2.4 QUALITY ASSURANCE FOR THE SUPPLY OF CONCRETE

2.4.1 All operations in the procurement of component materials and batching of concrete shall be carried out by a Contractor who works to a Quality Assurance scheme to BS EN ISO 9000 for those operations.

(NOTE. Advice for the Project Manager on Quality Systems is given in Appendix Y).

Each production unit involved in the work shall operate under a Quality Assurance scheme to BS EN ISO 9000. The Quality Policy Manual/s for the supply of component materials and batching of concrete, together with other relevant records and certificates, are to be submitted by the Contractor at Tender Stage.

(NOTE. The Project Manager should provide a questionnaire requesting details of information that are required; advice is given in sub-Clauses Y.5.2 and Y.6.4 of Appendix Y).

2.4.2 The Contractor shall be responsible for having all testing for the supply of concrete carried out in accordance with the requirements of Section 8 and shall provide the Project Manager with a written copy of the results in accordance with Clause 8.1.

2.4.3 All documentation relevant to the work, including test results, shall also be available at the plant or the depot for inspection. The documentation, including worksheets, shall be stored in an easily retrievable form for a minimum of 3 years.

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3 Constituent Materials

3.1 AGGREGATES, GENERAL

3.1.1 The contractor shall inform the Project Manager of the source and aggregate properties for each size of aggregate from each separate source of supply. The type of coarse aggregate to be used shall be crushed limestone; the type of fine aggregate shall be uncrushed, crushed gravel or rock, or blended.

(NOTE. Advice for the Project Manager on the acceptability of alternatives is given in Clause Z.1 of Appendix Z.)

3.1.2 Initial approval of aggregates shall be obtained from the Project Manager before mixing starts; approval shall be based on results supplied to the Project Manager of those tests listed in Clause 8.2 and carried out by the Contractor.

3.1.3 The Contractor (or Supplier on his behalf) shall operate under a Quality Assurance scheme to BS EN ISO 9000 with a scope appropriate for the production and supply of aggregates.

(NOTE. Advice for the Project Manager on Quality Systems is given in Appendix Y.)

3.1.4 Aggregates shall be clean, hard and durable as defined in Clauses 3.2 and 3.3. Aggregate shall not contain deleterious materials in such form or such quantity to adversely affect the strength at any age or the durability of the surfacing, including resistance to frost. Examples of such deleterious materials include:
- clay, loam or chalk, particularly as an adherent coating;
- mica, shale and other laminated materials;
- coal and other organic or vegetable impurities;
- sulphates and chlorides or other reactive substances liable to break down during drying or subsequent exposure to weather or moisture. Weathered rock shall not be permitted.

3.1.5 Aggregate soundness of each source shall be assessed using the Magnesium Sulphate Soundness Test in accordance with Appendix A on all fractions. [NOTE: This includes the fine fractions. BSEN1367-2 has details within its Annex C, and the full DIO requirement is contained within Appendix A of this specification which also provides example calculations.]

3.1.6 The water absorption of the aggregate shall be tested in accordance with BS EN 1097-6 :2013.

3.2 COARSE AGGREGATE

3.2.1 The coarse aggregate shall be crushed limestone.

(NOTE. Advice for the Project Manager on the acceptability of alternatives is given in Clause Z.1 of Appendix Z).

The coarse aggregate shall be supplied as, 10/20 and 4/10 single sized aggregates in compliance with BS EN 12620, Table 2.

[NOTE: Additional coarse aggregate size 20/40 may be used, however for slipform paving experience indicates that this may present practical difficulties]

3.2.2 The properties of the coarse aggregate, determined in accordance with the methods described in the relevant reference, shall fall within the limits shown in Table 3.1; the permissible test limits shall apply to each size from each separate supply source of aggregate.

TABLE 3.1 PERMISSIBLE TEST LIMITS FOR COARSE AGGREGATE

Test Property	Test Ref.	Permissible Limits
Particle Size Distribution	BS EN 933-1	20/40, 10/20 and 4/10 single sized, as BS EN 12620, Table 2
Chloride Testing	BS EN 1744-1:2009 +A1:2012	

Maximum Magnesium Sulphate Soundness Value	Appendix A	18 (Each source) 30 (Each fraction)
Max. Flakiness Index (%)	BS EN 933-3	25
Maximum Resistance to Fragmentation Value (Los Angeles coefficient)	BS EN 1097-2	35 (LA_{35})
Maximum Fines Content (%)	BS EN 933-1	4 (f_4)
Maximum Shrinkage (%) [1]	BS EN 1367-4	0.075
Water absorption	BS EN 1097-6	= or <2%

Notes:

1 Testing is only required if crushed rocks other than limestone are used.

2 Testing for magnetic permeability is only required for compass swinging bases or other locations indicated in the Contract documents (The limit for this is <1.005). The Project Manager shall provide the Contractor with details of a laboratory where magnetic permeability may be determined.

3.3 FINE AGGREGATE

3.3.1 Fine aggregate shall be:

- uncrushed;
- crushed rock or gravel; or
- blends of uncrushed fine aggregate and crushed rock or gravel

(all as defined in BS EN 12620) and shall be free from loosely bonded aggregations and other foreign matter.

3.3.2 The properties of the fine aggregate, determined in accordance with the methods described in the relevant reference, shall fall within the limits shown in Table 3.2; except for particle size distribution, the permissible limits shall apply to each size from each separate supply source of aggregate.

TABLE 3.2 PERMISSIBLE TEST LIMITS FOR FINE AGGREGATE

Test Property	Test Ref.	Permissible limits
Particle Size Distribution [1]	BS EN 933-1	As Gradings 1 or 2 in Table 3.3
Chloride Testing [3]	BS EN 1744-1:2009 +A1:2012	
Maximum Magnesium Sulphate Soundness Value	Appendix A	18 (Each source) 30 (Each fraction)
Maximum Fines Content (%)	BS EN 933-1	3 (uncrushed fine aggregate or crushed gravel fine aggregate) (f_3) 10 (crushed rock fine aggregate) (f_{10})
Water absorption	BS EN 1097-6	= or <2%

Notes:

1 Particle size limits shall be met by the aggregate as delivered or after blending two or more separate aggregates together before or during batching.

2 Testing for magnetic permeability is only required for compass swinging bases or other locations indicated in the Contract documents (The limit for this is <1.005). The Project Manager shall provide the Contractor with details of a laboratory where magnetic permeability may be determined.

3. Chloride testing is required at least once per production week to ensure that the limits for ASR are not exceeded (Qantab tests may also be used). Results of these tests are to be made available for review.

TABLE 3.3 GRADINGS 1 AND 2 FOR FINE AGGREGATE

BS EN 933-2 sieve size	Percentage by mass passing Grading 1	Grading 2
8.0 mm	100	100
4.00 mm	85 – 100	85 – 100
2.00 mm	50 – 90	70 – 97
1.00 mm	25 – 65	50 – 85
0.500 mm	13 – 30	30 – 55
0.250 mm	4 – 18	5– 25
0.125 mm	0 – 7	0 – 6

(1) A total tolerance of up to 5% may be applied to the percentages underlined in the Table. The tolerance may be split up. For example, it could be 1% on each of three sieves and 2 on another.
(2) For crushed rock fine aggregate, the permissible limit on the 0.125 mm may be increased to 15%.

3.4 CEMENTS & COMBINATIONS

3.4.1 Cements to BS EN 197-1:2011 may be CEMI, CEMII/A-S,CEMII/B-S,CEMIIB-S,CEMIIA-V&CEMIIB-V or combinations to BS8500 may be of CEM I TO BS EN 197-1:2011 with BS EN15167-1:2006 or BS EN 450-1:2012 (CIIA-S,CIIB-S,CIIA-V & CIIB-V

(NOTE. Advice on the use of cement is given in Clause Z.2 of Appendix Z).

3.4.2 The cement shall be strength class 42.5 N, or above, as defined in BS EN 197-1.

3.4.3 Each consignment shall be marked in the way described in Annex ZA of BS EN 197-1.

3.4.4 A test certificate shall be provided with each consignment giving the information in Table 3.4.

3.4.5 The certificate shall also state the alkali content of the cement expressed as the certified sodium oxide equivalent averaged over the manufacturer's latest 25 consecutive composite samples, together with an indication of variability. The determination for average alkali content must have been made on samples taken and prepared in accordance with BS EN 196: Parts 7 and 21 and determined in accordance with National Annex NA of Part 21. Any increase in the certified average alkali content of the cement must be notified immediately to the Project Manager

TABLE 3.4 INFORMATION REQUIRED ON DELIVERED CEMENT

Test Property	Test Ref.
Compressive strength at 2 or 7 days and 28 days from mortar prisms	BS EN 196 -1
Initial setting time	BS EN 196-3
Soundness (Expansion)	BS EN 196-3
Chloride content	BS EN 196-21
Type and quantity of additives (if > 1.0% (*m*/*m*))	

3.4.6 The current certificates shall be submitted to the Project Manager before mixing starts and thereafter throughout the course of the work for all consignments. If, in addition, the Project Manager calls for check tests on any consignment, this shall be arranged.

3.4.7 Fly ash shall comply with the requirements of BS EN 450 and certificates shall be submitted for the siliceous fly ash. No change shall be made to the source of fly ash once agreed without prior approval by the Project Manager.

3.4.8 Ground granulated blast furnace slag shall comply with the requirements of BS EN 15167. No change shall be made to the source of ggbs once agreed without prior approval by the Project Manager

3.5 WATER

3.5.1 Clean water, satisfying the requirements of BS EN 1008 shall be used.

3.5.2 When water is not available from a Water Authority or from the Establishment, the Contractor shall arrange for tests in accordance with the BS EN and shall submit the results to the Project Manager for approval before laying on the specified trial areas begins.

3.6 AIR ENTRAINING ADMIXTURE

3.6.1 The air entraining admixture shall be an approved product complying with BS EN 934-2. Air entraining plasticizers shall not be used.

3.6.2 Before mixing starts, a Certificate of Conformity to BS EN 934-6, and details of the proposed air entraining admixture, shall be submitted to the Project Manager for approval. This shall include evidence that the manufacturer of the admixture operates a Quality Assurance scheme to BS EN ISO 9001, based on the BSI/CAA Code of Practice for the application of BS EN ISO 9000 to the admixture industry, which is certified by a body accredited by NACCB.

(NOTE. General advice for the Project Manager is provided in Clause Z.3 of Appendix Z).

3.7 OTHER ADMIXTURES

3.7.1 *No admixtures, other than the approved air entraining admixture, shall be used.

OR

*If it is proposed to use a water reducing/plasticizing admixture, details shall be submitted to the Project Manager for approval before mixing starts. The details shall include:

- details of the proposed mixture and materials including a material specification
- evidence of successful laying and finishing elsewhere
- evidence that the mix will meet the specified strengths
- a Certificate of Conformity with BS EN 934-6
- evidence that the manufacturer of the admixture operates a Quality Assurance system to BS EN ISO 9001, based on the BSI/CAA Code of Practice for the application of BS EN ISO 9000 to the admixture industry, which is certified by a body accredited by NACCB.
- The manufacturer shall confirm that the proposed admixture and the proposed air entraining admixture can be used together without detriment.
- High range water reducing admixtures are permitted provided that ,when used in conjunction with an air entraining mixture, evidence that compatibility with the criteria in BS8500 Part 2 Clause 4.5 is obtained. .

(* NOTE. The Project Manager to select the option for a particular job specification; advice is given in Clause Z.4 of Appendix Z).

3.7.2 Admixtures containing chlorides shall not be used.

3.8 SEPARATION MEMBRANE

Where a separation membrane is used this shall be 125 microns thick impermeable polythene sheeting.

[NOTE: With machine lay paving a high level of surface regularity can be achieved on the underlying layer. Where hand lay is used a separation membrane is required. Where the underlying surface is rugous a separation membrane is required. Further advice is provided in Appendix Z]

3.9 JOINT FILLER

3.9.1 The joint filler shall be an approved manufactured filler meeting the requirements of the relevant tests in Appendix C.

3.9.2 For expansion joints, the thickness of the filler shall be 25 ± 1.5 mm.

3.9.3 Before laying on the specified trial area begins, a test certificate for the proposed joint filler shall be submitted to the Project Manager for approval. The certificate shall show compliance with the requirements of Appendix C by reporting the results of tests carried out by an independent laboratory within the six months immediately prior to the date on which it is proposed to start using the product on site.

3.10 CURING COMPOUNDS FOR EXPOSED SURFACES

3.10.1 The curing compound for Pavement Quality Concrete surfaces exposed immediately after finishing shall be an approved spray-applied resin-based compound containing flake aluminium in finely divided dispersion which will not separate out when the compound is applied and which will produce a complete coverage of the sprayed surface with a metallic finish. It shall become touch-dry within 5 minutes, stable and impervious to evaporation of water from the concrete surface within 60 minutes and shall not disintegrate for 3 weeks. When tested as described in BS 7542, the compound shall have an efficiency index of at least 90%. The compound shall not react chemically with the concrete. The rate of spread shall be in accordance with the supplier’s guidelines.

3.10.2 Before laying of the specified trial area begins, a Certificate of Conformity for the proposed curing compound shall be submitted to the Project Manager for approval. This shall include evidence that the manufacturer of the curing compound operates a Quality Assurance system to BS EN ISO 9001, based on the BSI/CAA Code of Practice for the application of BS EN ISO 9000 to the admixture industry, which is certified by a body accredited by NACCB.

3.10.3 Each consignment delivered to the site shall be clearly marked with the manufacturer's name and the name of the product and shall be accompanied by a certificate stating that the consignment is equal to the sample tested and giving the rate of spread necessary for the specified efficiency. Copies of the delivery certificates shall be passed to the Project Manager for his retention.

3.11 CURING LIQUIDS FOR VERTICAL FACES

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3.11.1 The curing liquid for vertical faces of Pavement Quality Concrete slabs cast against forms shall be bitumen emulsion complying with the requirements of Class A1-40 or A1-55 as specified in BS 434: Part 1, Table 1, or Class C40 B4 or C60 B3 as specified in BS EN 13808

3.11.2 The bitumen emulsion shall be delivered in weather-proof containers, each clearly marked by the supplier to show the class and bitumen content, or in bulk carriers accompanied by a certificate from the supplier stating the class and bitumen content of the consignment. A copy of each certificate shall be passed to the Project Manager for his retention.

3.12 JOINT SEALING COMPOUNDS

3.12.1 Joint sealing compounds may be of either hot applied or cold applied type. For hot application, an approved Type F1 compound complying with the requirements of BS EN 14188 : Part 1 shall be used. For cold application, an approved compound, either Type F or Type FB, as shown on the drawings complying with the requirements of BS 5212: Part 1 shall be used.

3.12.2 Only sealing systems which include separately applied primers shall be used and the primers shall be as recommended by the manufacturers of the sealing compounds. Compounds shall maintain adhesion with concrete which has been cleaned, dried and primed according to the manufacturer's instructions.

3.12.3 Sealing compound and primer shall be delivered in containers complying with the requirements of the relevant BS. Each consignment shall include a manufacturer's certificate containing the information listed in BS EN 14188: Part 1, Annex B or BS 5212: Part 1, Appendix B.

3.12.4 Before the specified trial area or any other area of concrete is sealed, either a Certificate of Conformity from a Quality Assurance system registered to BS EN ISO 9000 or an independent test certificate shall be submitted to the Project Manager for approval .

(NOTE. General advice for the Project Manager is provided in Clause Z.5 of Appendix Z).

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4 Design and Composition

4.1 DESIGN PROCEDURE

4.1.1 The Pavement Quality Concrete mixture shall be designed by the Contractor in his laboratory within the limits defined in Clauses 4.2 to 4.8 inclusively.

4.1.2 The suitability of the design shall be demonstrated by trial mixes and trial areas in accordance with Clauses 6.1 and 6.2.

4.1.3 After approval, changes of the constituents or changes in mixture proportions, beyond the routine adjustments needed to allow for variations in laying conditions or in gradings of aggregates as delivered, shall be made only with the agreement of the Project Manager and after repetition of trial mixtures and laying and approval of new trial areas.

4.2 AGGREGATE GRADING

4.2.1 When it is proposed to spread, compact and finish the concrete using a paving train or by semi-mechanised means, as specified in Clauses 5.17 or 5.18 respectively, the aggregates shall be combined so as to comply with the following requirements:

- The masses of the separate single sized coarse aggregates, as specified in Clause 3.2.2, in the mixture shall be *
- The mass of the fine aggregate, as specified in Clause 3.3, in the mixture shall be of a fixed proportion so that the mass of the fine aggregate is 30% - 37% of the total mass of the aggregate.

(* NOTE The Project Manager to complete for a particular job specification. Guidance is given in Clause Z.1.3 of Appendix Z).

4.2.2 When it is proposed to spread, compact and finish the concrete using a slip-form paver, as specified in Clause 5.18, the aggregates shall be combined so as to comply with the following requirements:

- The masses of the separate single sized coarse aggregates, as specified in Clause 3.2.2, in the mixture shall be *
- The mass of fine aggregate, as specified in Clause 3.3, in the mixture shall be of a fixed proportion so that the mass of fine aggregate is 32% - 40% of the total mass of aggregate.

(* NOTE The Project Manager to complete for a particular job specification. Guidance is given in Clause Z.1. 3 of Appendix Z).

4.3 MIXTURE PARAMETERS

The mixture shall be designed within the following limits:

- Minimum cement content (kg/m³ of fully compacted concrete): 350
- Maximum free water/cement ratio: 0.45
- Minimum total air content by volume,

20 mm maximum aggregate size: 5.0%± 1.5%

40 mm maximum aggregate size: 4.0%± 1.5%

The above figures relate to CEMI. Where other additions, e.g. fly ash or ggbs, are used the mix parameters will vary. The limits on substitution are 25% for fly ash and 35% for ggbs. Further guidance is given in Clause Z2 of Appendix Z

4.4 CONTROL OF CHLORIDES

[NOTE: In addition to precaution against chloride attack the chloride ion content is also used in the calculation for reactive alkali contributing to Alkali Silica Reaction - see Sect 4.5.5]

4.4.1 The total chloride ion content of the Pavement Quality Concrete mixture arising from cement, aggregates and any other constituent materials shall not exceed 0.4% of the mass of cement.

4.4.2 Chloride ion content shall be calculated in the manner shown in the following example:

Constituent	Mass	Chloride Ion Level	Chloride Ion Content
	(kg/m³ of concrete)	(%)	(kg)
Coarse aggregate	1200	0.04	0.48
Fine aggregate	600	0.10	0.60

Cement	350	0.07	0.25
Admixtures			0.12
Water (other than mains)			
Other sources			
Total Chloride Ion Content			1.45 kg

Total chloride ion content as a percentage of the mass of cement

$$\frac{1.45}{350} \times 100 = 0.41\,\%$$

The maximum value permitted is 0.40 %. Therefore, the mixture in this example does not comply.

4.5 PRECAUTIONS AGAINST ALKALI-SILICA REACTION

4.5.1 The total mass of reactive alkali in the Pavement Quality Concrete mixture shall not exceed 3.25 kg/m^3 calculated to the nearest 0.01 kg, in accordance with Clauses 4.5.2 to 4.5.5. [NOTE: Refer to Appendix Z 6.2 and Z13 for the possible special measures required should this limit impact on sources of fine aggregate, and to Z14]

4.5.2 Cement
The reactive alkali contributed by the cement in the concrete in kg/m^3 ("*A*") shall be taken as:

$$A = \frac{C \times a}{100}$$

where C = target mean cement content of the concrete mixture (kg/m³)
a = average alkali content of cement (% by mass of cement) (see Clause 3.4.5).

4.5.3 Aggregate
The reactive alkali contributed by chloride contamination of aggregates in kg/m^3 ("*H*") shall be taken as:

$$H = 0.76 \times Cl$$

where Cl = chloride ion content of aggregates (kg/m^3 of concrete)

4.5.4 Other Sources
The reactive alkali content of admixtures, water other than mains supply and other constituents of concrete in kg/m^3 ("*W*") shall be taken into account when determining the total alkali content of the concrete mixture.

4.5.5 Total Alkali Content
Total mass of reactive alkali = $A + H + W$ kg/m^3 of concrete.

4.6 STRENGTH

4.6.1 For F4.5 concrete and below the Contractor shall be responsible for constructing a Pavement Quality Concrete pavement slab such that the mean of the corrected core strength values at 28 days ± 3 days of cores cut from the slab, then cured, prepared and tested, all in accordance with Clause 5.28.1 and for trial areas Clause 6.2.6, is at least [43] (38) {34}* N/mm². Testing regimes and assessment of compliance shall be as described in Clauses 5.27.1 and for trial areas Clause 6.2. For F5 concrete and strengths above the relationship between cores, cubes and beams is to be established as indicated in sect 1.7v.

(*NOTE. For F4.5, 4.0 & 3.5 concrete the Project Manager to select one of the three alternative respective values and delete the other two. The corresponding values for strength requirements should then be selected throughout the Specification. For flexural strengths 5.0, 5.5 and 6.0 N/mm² beam testing is required as detailed in Sect 4.7 . Further guidance is given in Clause Z.2 of Appendix Z and the core, cube, and beam relationships indicated in sects 1.7 v & vii are to be derived for all flexural strengths (including 4.5 N/mm² and below for DIO/industry research purposes).

For the purpose of clarity further sections in this specification provide compressive strength figures for the strength values 4.5, 4.0, 3.5 N/mm² using CEM1 only. These figures continue to be represented by the distinctive bracketing, [ ] ( ) { }*)

4.6.2 The mean of 7 day cube strength values shall be at least [45] (40) {35}* N/mm². This value shall be increased if the Contractor considers it necessary, to ensure that the requirement of Clause 4.6.1 will be realised. Testing regimes and assessment of compliance shall be as described in Clauses 5.15.2 and (for trial areas) 6.2.

(*NOTE. The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and delete the others).

4.7 BEAM TESTING , CORES, CUBES

The flexural strength of beams (500mm sized) shall be tested in accordance with BS EN 12390-5 and the relationship between beam tests, core strengths and cube strengths is to be established (see Appendix Z2) .

For F4.5 and below this information is for DIO/industry research purposes and the testing will be a minimum of three each 7& 28 day beams, three each 7& 28 day cubes and three 28 day cores

For F5.0 and above the number of tests shall be a number commensurate with establishing the relationship between cubes, cores and beams and with providing sufficient assurance that the design requirements are met in the as constructed pavement.

Where cement additions are used this shall also be the requirement.

4.8 CONSISTENCE (WORKABILITY)

The concrete shall be of a consistence suitable for full compaction without undue flow to be achieved with the plant used.

5 Plant, Workmanship and Production Testing

5.1 STORAGE OF MATERIALS

5.1.1 All materials shall be stored in accordance with manufacturers' instructions. They shall be protected against damage by the weather or by exposure to extremes of temperature.

5.1.2 Materials condemned by the Project Manager shall be removed immediately from site.

5.1.3 Cement shall be kept dry until use. It shall be protected from the weather during transit. If delivered in bulk containers it shall be stored on site in silos. If delivered in bags or drums it shall be stored in a weatherproof building on a raised floor or platform. Each consignment shall be kept separate from previous consignments. The cement shall be used in the order of delivery. Cement held on site for more than 28 days shall satisfy the requirements given in Table 3 of BS EN 197-1. [NOTE: Chromium VI build up may be a H&S issue for cement stored for lengthy periods]

5.1.4 Bitumen emulsion shall be protected from freezing. Drums in store shall be turned or inverted at least once a month.

5.2 STORING AND HANDLING AGGREGATES

5.2.1 Aggregate stockpiles shall be on concrete or other approved hard surfaces, laid to falls to allow unrestricted drainage. The siting and preparation of the sites shall be approved by the Project Manager. Aggregates shall be stockpiled separately for each size delivered from each source of supply. Each size from each source shall be separated in the stockpiles by sturdy bulkheads.

5.2.2 The methods to be adopted to prevent overspill between adjacent stockpiles, "coning" or segregation of the aggregate in the stockpiles, particularly during tipping, shall be agreed with the Project Manager. Care shall be taken to avoid crushing by stockpiling equipment.

5.2.3 The aggregates shall be kept free from contact with deleterious matter.

5.2.4 Aggregates containing more than 5% passing a 4 mm sieve shall not be batched until they have been deposited for at least 8 hours. All aggregates produced or handled by hydraulic methods or which have been washed shall be stockpiled for at least 24 hours before batching.

5.2.5 Aggregates shall be handled from the stockpiles to the batching plant by means which avoid contamination and minimize segregation.

5.3 TESTS ON AGGREGATES FROM STOCKPILES

5.3.1 The particle size distribution of a representative sample from each stockpile of each aggregate shall be determined once a day when mixing and laying are in progress. The samples shall be taken in accordance with the requirements of BS EN 932-1, prepared according to BS EN 932-2 and the testing shall be by wet sieving as described in BS EN 933-1. If any of the particle size distributions so determined falls outside the relevant limits given in Clauses 3.2.3 or 3.3.2, two further tests shall be carried out. If either of these also fails to satisfy the requirement, mixing shall cease immediately and the non-complying aggregate shall be removed and replaced with material complying with the specified requirements.

5.3.2 The fines content of each size of aggregate from each source shall also be determined when mixing and laying are in progress. Samples shall be taken in accordance with the requirements of BS EN 932-1, prepared according to BS EN 932-2 and the tests shall be performed by the method described in BS EN 933-1.

5.3.3 A qualitative test for the presence of chloride ions (as described in BS EN 1744-1) in coarse aggregate and fine aggregate shall be carried out before mixing of concrete for the Works begins and at weekly intervals thereafter. The samples for test shall be taken from the base of each stockpile. When this test shows the chloride ion content of an aggregate to be other than negligible, the water-soluble chloride ion content of a sample of the same aggregate taken from the base of the stockpile shall be determined. The test method used shall be that described in BS EN 1744-1. The value/s determined shall be used in the calculation of total chloride ion content of the concrete mixture specified in Clause 4.4.

5.4 BATCHING AND MIXING OF CONCRETE

5.4.1 Concrete shall be mixed in an approved static volumetric or a batch mixer complying with the requirements of Clause 5.5. The mixer shall be controlled by an experienced operator.
[NOTE: In some circumstances e.g. remote sites and some small scale works, mobile volumetric mixers may be used with Project Manager consent following consultation with DIO Airfield Pavements Team]

5.4.2 The proportion of each constituent in the mixture by weight shall be that approved by the Project Manager in accordance with Clauses 6.1 and 6.2, allowance being made as detailed below for the weight of free water in the aggregate.

5.4.3 The allowance made for free water in the aggregates shall be determined on representative samples from each of the aggregate stockpiles in accordance with the methods described in BS EN 1097-5, or, with the agreement of the Project Manager, by another method. Regular determinations shall be made before mixing starts each day and, unless moisture meters are fitted at the discharge points from the bins containing 10 mm and smaller aggregate sizes, afterwards at 4-hourly intervals until mixing ceases for the day. Additional determinations shall be made when mixing restarts after rain has stopped production or when moisture meters in the bins indicate a change in moisture content. Following each determination of free water in the aggregates, the precise quantity of added water required to make up the total proportion of mixing water approved shall be recalculated.
[NOTE: The above may be addressed when moisture meters are installed in plants and computerised methods are used to control the addition of water]

5.4.4 Aggregates from each stockpile and cement shall each be proportioned separately by weight to the tolerances given in BS EN 206-1, Table 21. When the cement is delivered in bags, proportioning by weight of all constituents shall be based on the incorporation of whole bags.

5.4.5 The added water content calculated as described above shall be measured by either weight or volume to the tolerances given in BS EN 206-1, Table 21. All of the mixing water required for each batch shall be added in the approved mixing plant.

5.4.6 Each admixture shall be measured separately at the mixer in preset automatic dispensers to within ± 5 % of the quantity approved for the mixture. Admixtures shall be added with the water and the mixing time shall be such as to ensure uniform distribution of the admixture throughout the batch.

5.4.7 Mixing within an approved static mixer shall continue until a well mixed homogenous concrete has been produced. The total mixing time shall be agreed following trials with the mixture and mixing shall be carried out for this period. The consistency of each amount of concrete shall be checked by use of a wattmeter monitoring the power supply to the mixer, or other proven reliable device, and each amount of concrete shall be inspected prior to discharge.

5.4.8 Mixers shall be emptied before being charged with a new amount of concrete. When a delay in excess of 30 minutes occurs during concrete production, mixing shall not restart until the mixer and handling plant have been thoroughly cleaned out.

5.5 CONCRETE MIXERS

5.5.1 The Contractor shall submit for approval, with his tender, details of the mixer(s) he proposes to use, including the manufacturer's name, type of mixer and estimated output. The Contractor's proposals will be considered and, if requested, he shall also submit at tender stage the following further information:

- A technical description of the plant, including recommended methods of maintenance and operation control.
- Minimum mixing time recommended for Pavement Quality Concrete.
- Time required for charging and discharging.
- Estimated theoretical output in terms of unit time for Pavement Quality Concrete.
- Batch size.
- *Method of addition of air entraining admixture.
  or
  *Method of addition of air entraining admixture and other admixture.
- Type of water measuring device.
- Any other information concerning the ability of the plant to produce Pavement Quality Concrete of consistent proportions and properties to the

requirements of this Specification and at a rate of output suitable for the laying plant and programme proposed.

Only mixing plants approved as a result of these submissions shall be used.

(*NOTE. The Project Manager to select the option corresponding with the requirement selected at Clause 3.7.1).

5.5.2 The batching plant(s) and mixer(s) shall be set up within the site boundary in a location approved by the Project Manager.

5.5.3 The weighing mechanism of each batching plant shall be checked either by its manufacturer or by an independent testing authority who shall certify compliance within the tolerances given in BS EN 206-1, Clause 9.6.2.2. A copy of the certificate shall be passed to the Project Manager before mixing begins. Further checks shall be made and the certificates passed to the Project Manager at the end of each agreed period during mixing and whenever a mixer is re-sited or disturbed.
[NOTE: The period is typically quarterly or may be monthly if requested]

5.5.4 The calibration of the water measuring devices and admixture dispensers shall be checked before mixing begins and at monthly intervals during mixing. Copies of the certificates shall be passed to the Project Manager. In addition, the Contractor shall himself check the accuracy of the devices and dispensers to the satisfaction of the Project Manager before mixing begins.

(NOTE. General advice for the Project Manager is provided in Clause Z.7 of Appendix Z).

5.6 SLAB THICKNESS

The pavement thickness shall be the arithmetic mean of the individual core lengths and shall be not less than the design thickness shown on the Project drawings. Any individual core length shall be not less than the design thickness with the T5 category tolerance given in Table 4 of BS EN 13877-2. The finished levels and surface regularity shall meet the requirements of Clause 5.22.

5.7 LAYOUT OF JOINTS

* The layout of the joints shall be as shown on the Project drawings.

Or

* As an alternative to the joint layout shown on the drawings, the Contractor may design the layout of the joints to suit his plant and equipment and shall submit his proposals at the 100% design stage to the Project Manager for approval. The layout shall conform to the following requirements:

- Drawings shall be to a scale of 1/500 or 1/200, as appropriate for the size and shape of the pavements.

5.8 WEATHER CONDITIONS

5.8.1 Cold Weather

The following requirements shall be met:

- Aggregates which are frozen or contain ice or snow shall not be used.
- Salt shall not be used to prevent freezing.
- Calcium chloride or other accelerators shall not be used.
- Concrete shall not be spread when the air/shade temperature is 2°C or lower. Alternatively, with the approval of the Project Manager, the Contractor may take measures to maintain or generate sufficient heat in the aggregates and water to ensure that the temperature of the concrete during mixing, spreading, compacting and finishing does not fall below 10°C. When temperatures below 0°C are forecast or occur unexpectedly, concrete which has been laid for less than 6 days shall be protected from frost damage by securely-fixed insulation which shall remain in position for at least 6 days after the concrete is laid. Examples of suitable insulating materials are:
  - expanded polystyrene sheeting.
  - extruded polyethylene foam sheeting.
  - straw mats at least 100 mm thick.

  All insulation material shall be maintained in good condition and shall remain securely fastened for as long as it is being used. After use it shall be removed from the airfield.
- Concrete damaged by frost shall be removed for the full thickness of the slab and replaced by the means specified in Clause 5.32.
  [NOTE: The Britpave Publication BP01 “Concreting Pavements in Winter” January 2012 provides further detailed guidance .With regard to early age protection. 2N/mm^2 compressive strength is to be achieved before the protection is removed].

5.8.2 Wet Weather

The following requirements shall be met:

- Concrete shall not be laid during rain. Alternatively, with the approval of the Project Manager, the Contractor may provide suitable protection to the concrete during transportation and placing to enable completion of the finishing

processes (including the necessary joint forming) to a standard equal to that of the approved trial area.
- All precautions necessary shall be taken to protect freshly placed concrete from rainwater running off adjacent areas.
- Where a new concrete surface is damaged by light rain, the surface may be re-textured to a standard equal to that of the approved trial area, provided that the re-texturing is completed within the time constraints specified in Clause 5.21. Re-texturing of surfaces affected by heavy rain or surface run-off from other pavement areas is not permitted.
- Surfaces directly affected by light rain, whether re-textured or not, shall be tested in accordance with Clause 5.27.3 to ensure adequate surface texture has been achieved.
- Surfaces affected by heavy rain or run-off from other pavement areas shall be broken out and replaced in accordance with Clause 5.32.

5.8.3 Hot Weather

When the air/shade temperature is above 25°C, or has been above 25°C in the previous 24 hours, the temperature of the fresh concrete shall be measured when mixing begins and at hourly intervals during mixing using the method described in BS 8500-2, Clause 5.4. Concrete of temperature above 30°C shall not be placed and all necessary measures shall be taken to achieve a uniform temperature below 30°C in the concrete at the time of placement.

5.9 REGULATION OF EXISTING SURFACES

5.9.1 When existing pavement surfaces are to be overlain with new Pavement Quality Concrete, if there are areas where the depth of new construction to finished slab levels will exceed the design slab thickness and tolerance, as specified in Clause 5.6, the levels in these areas shall be regulated in advance of concreting. The materials to be used in regulating shall be in accordance with Table 5.2. The edge of the regulating material shall be feathered out, not finished in an abrupt step.

TABLE 5.2 MATERIALS FOR REGULATION

Material	Maximum Aggregate Size (mm)	Permitted Layer Thickness (mm)
*Rolled Dry Lean Concrete (CBGM)	40	75 - 200
*Marshall Asphalt		
	32	50 – 100
	20	30 – 70
	14	20 – 60
	10	20 – 40
* *Asphalt Concrete (Macadam)):*		
Dense binder course	32	50 – 100
Dense binder course	20	30 – 70
Dense surface course	6	20 – 40
Fine Graded	2	Up to 30
**Hot Rolled Asphalt*		
Designation 55% 0/14	14	25 – 60
Designation 55% 0/10	10	20 – 50
Designation 0% 0/2	2	Up to 30
*Stone Mastic Asphalt (SMA)		
	20	50 - 100
	14	35 - 60
	10	25 – 50
	6	20 – 50
	2	Up to 25

(*NOTE: The Project Manager to insert requirements. Specifications for Marshall asphalt, macadams, hot rolled asphalt and SMA are contained in separate DIO Specifications).

5.9.2 When tested by the method described in Appendix B, the divergence between the bottom of the straight edge and the finished surface of the regulating material shall not be more than 10 mm and shall show no abrupt steps.

5.10 PREPARATION OF UNDERLYING SURFACES

5.10.1 All vegetable growth and loose particles shall be removed from the surface.

5.10.2 All joints and cracks 20 mm or more wide in the existing pavement shall be filled with lightly compacted 0/2 mm size fine graded macadam surface laid to a convex finish slightly proud of the general surface level. All other joints or cracks shall be levelled by removing extruded material to a finish flush with the adjacent surface level. Potholes shall be also be made good with 0/2 mm size fine graded macadam or, alternatively, with hot rolled asphalt, Designation 0% 0/2.

5.10.3 Before the separation membrane specified in Clause 3.8 is laid, the surface shall be clean, smooth and free of standing water, mud, grit and other extraneous matter.

5.11 JOINTS BETWEEN NEW PAVEMENT QUALITY CONCRETE AND EXISTING BITUMINOUS SURFACING

5.11.1 The joints shall be made in accordance with Figure 5.1.

5.11.2 The existing bituminous pavement shall be cut back from the line of the junction between the bituminous pavement and the new concrete pavement by a maximum distance of 500 mm to permit the erection of the forms specified in Clause 5.12 or to allow the passage of the side forms of a slip-form paver. The drylean concrete base shall then be carried through to abut the cut-back edge of the existing pavement. If the existing bituminous pavement is thicker than the new pavement, the extra thickness at the base of the pavement in the cut back area shall be restored with drylean concrete, laid and compacted in separate layers if necessary to comply with the specified requirements for maximum drylean concrete layer thicknesses. After the specified forms have been fixed on the surface of the drylean concrete, the new Pavement Quality Concrete surfacing shall be completed.

5.11.3 Immediately after the forms have been removed, or, when a slip-form paver has been used, prior to refilling the space between the new concrete and the bituminous surfacing, the exposed vertical edge of the new concrete slab shall be painted or sprayed with the bitumen emulsion specified in Clause 3.11. The space between the new concrete slab and the existing pavement shall then be filled with drylean concrete compacted to within 100 mm of the surface of the new slab. The remainder of the space shall be filled with hot rolled asphalt complying with BS 594-1, Designation 35% 0/14 incorporating crushed rock aggregate and 70/100 pen bitumen binder. Before any asphalt is placed, all exposed surfaces to which it is to be bonded shall be tack-coated in accordance with BS 434-2, Clause 14. The asphalt shall be placed in two layers, each of 50 mm and separately compacted. At the time of compaction the temperature of the mixture shall not be less than 120°C. The final layer shall be laid slightly proud of the existing asphalt surfacing. Hand tampers shall have a mass of not less than 25 kg and a face area not exceeding 0.065 m^2.

5.11.4 Where ramps are to be provided between new Pavement Quality Concrete and existing bituminous pavements, these shall be constructed to the details shown on the Project drawings.

5.12 FORMS

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5.12.1 Forms for use in hand-laid bays specified in Clause 5.17 shall be purpose made right angled steel road forms, provided with adequate devices for secure setting so that when in place they will withstand, without springing or settlement, the impact and vibration of the compacting and finishing plant. The depth of the forms shall be adequate to support fully the slab thickness specified in Clause 5.6 or on the drawings. The thickness of any packing beneath the forms shall not exceed 30 mm. Timber forms may be used to make up odd shaped/odd lengths bays subject to approval of Project Manager.

5.12.2 The forms and rails shall be kept free from dirt, mud and other extraneous matter.

5.12.3 Forms shall be set to the correct line and level and packed underneath with Portland cement mortar. The mortar shall not extrude beyond the vertical inside face of the forms. The sections shall be tightly joined by locked joints free from play in any direction.

5.12.4 The line and levels of all forms shall be checked and corrected, if necessary, immediately before the concrete is placed. The vertical inside faces and tops of the forms shall be inspected to see that they are clean and shall be generously oiled to ease removal.

5.12.5 Forms shall not be removed until concrete is sufficiently strong so as to prevent damage. Mortar packing left alongside the finished slabs shall be removed before adjacent slabs are poured.

5.13 PLACING SEPARATION MEMBRANE

5.13.1 Where required the separation membrane, subject to complying with the requirements of Clause 3.8*, shall be laid flat on the surface without folds or ripples. Except where it is laid in strips beneath forms to comply with the requirements of

Clause 5.13.2, the membrane shall be laid immediately before concrete is spread. It shall be secured without puncturing against disturbance by the wind. Laps between sheets shall not be less than 150 mm in any direction.

5.13.2 The membrane shall be laid beneath all joints with the laps specified. Damaged or torn sheets shall not be used. Standing water on the sheet shall be removed before concreting is allowed to commence. Any sheets which become torn or damaged before concrete is spread shall be replaced or overlain with additional sheets.

[NOTE. With machine lay paving a high level of surface regularity can be achieved on the underlying layer. Where hand lay is used a separation membrane is required. Where the underlying surface is rugous a separation membrane is required. Further advice is provided in Appendix Z12].

5.14 TRANSPORTING CONCRETE MIXTURES

5.14.1 Freshly mixed concrete shall be transported to the laying site without segregation or loss of constituent materials. It shall be covered during transit and while awaiting discharge to prevent wetting by rain or evaporation of moisture.

5.14.2 Sufficient delivery vehicles shall be used to maintain a continuous supply of concrete to the paving plant.

5.15 TESTS ON FRESH CONCRETE

5.15.1 Consistence (Workability)

5.15.1.1 Samples of concrete for Degree of Compactability/Compaction Index (CI) tests shall be taken in accordance with the methods described in BS EN 12350-1 and tested in accordance with the methods of BS EN 12350-4.

5.15.1.2 A sample of concrete for a Compaction Index test shall be taken at the same time and from the same location as each sample for the preparation of test cubes (see Clause 5.15.2). In addition, for each mixer in use, samples shall be taken for test from the first delivery of concrete each day, from the first delivery on restarting after an interruption to mixing of more than one hour and at intervals of not more than one hour during production.

5.15.1.3 If more than 3 Compaction Index values out of 20 consecutive results fall outside the tolerance given in Table 11, BS EN 206-1 of the job standard Compaction Index value determined during the laying of the trial areas specified in Clause 6.2, then mixing shall stop and adjustments shall be made to ensure compliance when mixing restarts.

[NOTE: As an alternative to using Compaction Index the Compacting Factor Test to BS 1881 Part 2 may be used. These tests may also be complemented with slump tests].

5.15.2 Compressive Strength of Cubes

5.15.2.1 Samples of concrete for making test cubes shall be taken in accordance with the methods described in BS EN 12350-1. Each sample shall be taken from a single batch of concrete selected by the Project Manager. From each sample, two 100 (or 150) mm cubes shall be made in accordance with BS EN 12390-1 and BS EN 12390-2. The cubes shall be cured and tested for compressive strength at 7 days in accordance with BS EN 12390-2 and BS EN 12390-3, respectively. The mean of the results from each pair shall be taken as a test result. When the difference between a pair of results divided by their mean exceeds 15 %, the result shall be deemed invalid and shall be excluded from compliance assessment.

5.15.2.2 For the first 500 m^3 of routine production of Pavement Quality Concrete, a sample from each 25 m^3 of concrete laid, or one from each day's production when this is less, shall be taken for making test cubes. Thereafter, the rate shall be one sample per 50 m^3 of concrete laid or one per day.

5.15.2.3 The mean values for the set of test results representing the first 500 m^3 of normal production and for subsequent sets each representing 1000 m^3 of production shall be not less than [45] (40) {35}* N/mm^2. If the mean of any set of results falls below this value, the batching and mixing procedures shall be checked immediately and if necessary the mixture shall be adjusted to improve its strength.

(*NOTE: The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and to delete the others).

5.15.2.4 If any individual cube test result falls below [34] (30) {26}* N/mm^2, four 100 (or 150)mm diameter cores shall be cut from the pavement slab in the location corresponding with the delivery of concrete from which the test sample came. The cores shall be cut at 5 m spacings and shall be additional to the routine test cores specified in Clause 5.27.1. The four cores shall be cured, prepared and tested as described in Clause 5.27.1. The mean 28 day corrected core strength of the four cores shall be at least [36] (31) {28}* N/mm² and no more than one individual value shall be below [32] (28) {25}* N/mm². If either or both of these requirements are not realised, the area of pavement slab represented by the four cores shall be condemned. This area shall be taken as the 20 m length of the pavement lane symmetrical about the core positions. The extent of any further unacceptable concrete in either direction adjacent to the condemned area shall be investigated by cutting and testing additional cores as described in Clause 5.27.1.

(*NOTE: The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and to delete the others).

5.15.3 Air Content

5.15.3.1 Samples of concrete for air content determinations shall be taken in accordance with the methods described in BS EN 12350-1. The air content shall be determined by the method described in BS EN 12350-7. Sampling and testing shall be at the point of delivery to the paving plant.

5.15.3.2 An air content determination shall be made from each delivery sampled for a Compaction Index or Compacting Factor test. The aggregate correction factor shall be checked periodically and a new determination made whenever the aggregates or aggregate proportions are changed.
(NOTE: for limited extent hand lay work the slump test may be used with Project Manager approval).

5.15.3.3 If any air content determination indicates that the total air content of the fresh concrete is not within the limits specified in Clause 4.3, two further determinations on the same or next delivery shall be made. If either of these also fails to satisfy the requirement, then mixing shall stop and adjustments shall be made to ensure compliance when mixing restarts.

5.16 PLACING CONCRETE

Unless otherwise approved by the Project Manager, the concrete shall be laid in lanes parallel with the pavement centre line.

5.16.1 The concrete shall be spread, compacted and finished by a method complying either with Clause 5.17 or 5.18

(*NOTE: The Project Manager may include one or both of Clauses 5.17, 5.18 in a particular specification, according to the scale and disposition of the work. Advice is given in Clause Z.8 of Appendix Z).

5.17 SPREADING, COMPACTING AND FINISHING CONCRETE BY SEMI-MECHANISED MEANS*

(*NOTE: PQC is laid by slipform paving machines or by semi mechanised means. The Project Manager may include one or both of Clauses 5.17, 5.18 in a particular specification, according to the scale and disposition of the work. Advice is given in Clause Z.8 of Appendix Z).

5.17.1 . The hand lay concrete shall be tipped or discharged from mixer truck across the width of the rip. A rubber tyred excavator shall then fully spread the concrete between the forms.

5.17.2 The concrete shall be spread to give a surcharge which will vary with compacting fraction or compaction index
[NOTE: typically this is approximately 25% of the finished depth].

5.17.3 The method of spreading, surcharge height and finishing will be demonstrated in the laying trials described in section 6 and the following paragraphs are intended to provide the minimum standards expected from those trials.

After internal vibration, the concrete shall be struck-off at sufficient level above the forms to ensure that during surface vibration the concrete is everywhere in contact with the compacting beam.

5.17.4

Poker vibrators, either hand held or mounted on to excavator bucket are to be used to compact the concrete. The vibrators shall be a minimum of 50 mm diameter and shall be inserted full depth at centres of not more than 500 mm in both directions. They shall remain in place until either all the air bubbles have stopped or until the pitch of the poker lowers.

5.17.5 Once the concrete has been uniformly compacted a finishing beam which rests on the forms shall be drawn over the bay to give level and finish. It may be necessary to repeat this operation to ensure tolerances are met and that the surface is free from blemishes, however this process should be kept to the absolute minimum and overworking shall not be permitted. Care must be taken to ensure that the beam is not pushing fat over the surface. Hand held trowels and floats may be used to remove any remaining blemishes After internal vibration, the concrete shall be struck-off at sufficient level above the forms to ensure that during surface vibration the concrete is everywhere in contact with the compacting beam.

5.17.6 Quickly after the finishing process in 5.17.5 has been carried out the surface shall receive a final pass with a transverse float. This float will remove excess laitance and any irregularities in advance of the texturing and curing processes.

5.17.7 The end of day joint must be planned to coincide with the transverse joint pattern. Care must be taken to ensure that sufficient fresh concrete is available to make up the joint and that sufficient and backup drills and equipment are available to install the pre-made steel day joint form. Immediately following the completion of compaction but before texturing or application of the curing liquid, scraping straightedges shall be used to remove laitance and minor irregularities from the surface. A scraping straightedge shall have a 3 m long blade and a flexible handle of sufficient length to reach across the width of a concrete lane. An example is shown in Figure 5.3, but alternative designs may be proposed to the Project Manager for approval. Floats shall not be used. Concreting shall not commence until approval has been obtained. Induction cuts will be required in the hand lay concrete and therefore it will be necessary to locally remove forms at joint positions so that sawcuts can be made to the full extent.

5.17.8 When striking forms, particularly the end of day joints care must be taken not to damage the ends and it may be prudent to plan works so that transverse joints are not laid up against until the concrete gains strength, a consideration of particular importance in cold weather conditions.

5.17.9 The scraping straightedge shall be operated by two persons, one on either side of the concrete lane. While the concrete is still plastic and workable, the blade of the straightedge shall be carefully positioned on the surface of the concrete and parallel to the forms. The blade shall be worked uniformly backwards and forwards across the full width of the lane by the first person until all irregularities and blemishes have been removed from the surface of the concrete. The blade shall then be picked up on the other side of the lane by the second person, cleaned and moved along the lane by not more than half the blade length. The scraping process shall then be repeated.

5.17.10 The concrete surface shall not be overworked. Hand floating shall not be allowed, apart from the minimum required to finish alongside joints.

5.17.11 With his tender, the Contractor shall give details of the equipment he proposes to use, together with a detailed methodology for the spreading, compacting and finishing operations. If the Contractor's proposals are considered satisfactory in principle, a qualified preliminary acceptance of the equipment will be given by the Project Manager prior to the letting of the contract. Final approval to the equipment and methods shall rest with the Project Manager on the basis of their performance during the laying of the trial areas specified in Clause 6.2. General laying of concrete shall not begin until final approval has been obtained.

5.18 SPREADING, COMPACTING AND FINISHING CONCRETE BY SLIP-FORM PAVER*

(*NOTE: The Project Manager may include one or both of Clauses 5.17, 5.18 in a particular specification, according to the scale and disposition of the work. Advice is given in Appendix Z8

5.18.1

The concrete shall be spread, compacted and finished in a continuous operation. The paving machine shall consist of a prime mover and a rigid mould/beam which is mounted below or to the side of the prime mover. The prime mover provides variable forward/reverse travel and hydraulic power.

Compaction is achieved by means of internal vibrators mounted at a height and spacing across the mould/beam. The height and spacing are dependent on the manufacturer’s declared frequency of the vibrators. The weight and rigidity of the mould/beam shall be sufficient to enable the concrete to be laid consistently to required levels and profiles within the tolerances permitted in this Specification*.

(*NOTE: The weight and rigidity of the paver mould/beam should be at least equal to that provided by a 5000 Series mould).

5.18.2
The concrete shall be deposited in front of the slip-form paver across its whole width. The concrete shall be “re-mixed” using excavator or auger to ensure there is no segregation. The deposited concrete shall be struck-off to the necessary differential surcharge or “head” by means of a quickly adjustable strike-off plate or a pre-set auger extending across the whole width of the lane. The “head” must be maintained at the correct level and width at all times.

5.18.3
The level of the conforming plate shall be controlled automatically from the guide wire(s) or 3D system specified in Clause 5.18.5 by sensors attached at the four corners of the slip- form paving machine. The alignment of the machine shall be controlled automatically by at least one sensor attached to it. Alternatively line and level can be from a machine guidance system which uses a 3D model and total stations to control the position of the conforming plate. The details of the system shall be provided to the project manager. The conforming plate shall be calibrated to the control system prior to paving commencing and the contractor shall submit evidence to the Project Manager that the controls can comply with the specification requirements including how slab depth is checked and regulated. A detailed methodology of how the system operates and how corrections are made including the roles of the surveyors, machine operators and supervisors shall be submitted prior to paving commencing.

5.18.4
The slip-form paving machine shall have vibration of variable output to suit different concrete mixture characteristics, slab widths and thicknesses and rates of progress. To this end the vibrators must be able to be moved whilst in the concrete. The compacted concrete when hardened shall satisfy the test requirements specified in Clause 5.27. The machine shall have sufficient power and mass to maintain uniform forward movement during the placing of concrete in all situations. Side forms shall be rigid enough to deal with all slab depths.

5.18.5
Where it is used, a guide wire shall be provided along each side of each lane to be laid by slip-form paving plant. This may be reduced to a single wire if the machine is working from skids on a lane already laid or with a constant crossfall device from the one wire. Each guide wire shall be at a constant height above the projected finished level as shown on the drawings and parallel to the required line of the lane joint within a vertical tolerance of ± 3 mm. Additionally, one of the wires shall be at a constant horizontal distance from the required line of a lane joint within a lateral tolerance of ± 6 mm. The guide wires shall be supported from stakes not more than 8 m apart by connectors capable of fine vertical and horizontal adjustment.
The ends of the guide wires shall be anchored to fixing points which shall not be closer to the edge of the slab than the line of stakes. The ends of the guide wires shall not be anchored to the stakes.

5.18.6
Finishing behind the slip-form paving machine shall be carried out by means of an adjustable stainless steel trowelling section and an adjustable finishing beam. The trowelling section is to be part of the mould/beam and should be set with a slight lead to “polish” up the concrete and so remove imperfections.
The finishing beam shall be set to pass over the concrete with sufficient pressure to bring a minimal amount of laitance to the surface. The combination of trowelling section and finishing beam should be sufficient to bring the concrete to the stage where a final pass of a hand held box float means that the concrete is ready to receive the texture described in sect 5.21.
The concrete surface shall not be overworked and hand floating shall be kept to a minimum to remove any minor blemishes or imperfections. Forward travel speed may be altered to adjust finish if necessary.
Particular attention must be applied to the free standing edges of the slab. Trailing forms may be used to control any edge slump and edge slump must be checked using straightedges as the paver travels forward.
The vertical faces of the slab should also be finished so that no major imperfections remain.

5.18.7
Edge slump may also be corrected by using purpose made forms with adjustable jacks. Edge slump must also be checked after the texture described in sect 5.21 has been applied. Sufficient forms for a continuous length of 50 m of joint shall be available for use at the beginning of each laying shift.

5.18.8
All units shall be properly maintained.

5.18.9
The units shall be controlled by experienced operators at all times.

5.18.10
With his tender, the Contractor shall give details of the equipment he proposes to use, together with a detailed methodology for the spreading, compacting, finishing, texturing and curing operations. If the Contractor's proposals are considered satisfactory in principle, a qualified preliminary acceptance of the equipment will be given by the Project Manager prior to the letting of the contract. Final approval to the equipment and methods shall rest with the Project Manager on the basis of their performance during the laying of the trial areas specified in Clause 6.2. General laying of concrete shall not begin until final approval has been obtained.

5.19 EXPANSION JOINTS

5.19.1 Expansion joints shall be formed as shown in Figure 5.1. They shall be vertical and straight. The pavement surfaces across the joints shall be finished so as to satisfy the regularity test requirements specified in Clause 5.27.2.

5.19.2 Expansion joints between new and previously laid or existing concrete pavements, around box-gutters and around other obstructions to the continuity of the new slab shall be formed by placing the approved 25 mm thick joint filler specified in Clause 3.9 against the exposed face of the existing slab, gutter or obstruction prior to the laying of the concrete. Only where lengths of joint filler greater than the standard length for the approved product are required shall two lengths be butt jointed together. The filler shall be rigidly held in position so that it cannot be displaced or disturbed during subsequent concreting. All necessary measures shall be taken to ensure that “bridging” with concrete does not occur beneath or around lengths of filler.

5.19.3 Main expansion joints may be preformed in advance of concreting by placing the joint filler in the required location prior to the laying of the concrete. The filler shall be held rigidly in position against a steel channel secured firmly to the surface on which the concrete is being laid, or in an approved cradle assembly designed for the purpose and equally rigid and well secured, which cannot be displaced or disturbed during subsequent concreting. The filler shall extend the full depth of the joint with no gap between the bottom of the filler and the surface on which it is resting. The concrete shall be spread, compacted and finished up to the filler on one side and, after initial set of the slab against the filler, the channel or cradle shall be removed before concrete laying is continued from the other face of the filler.

5.19.4 45 degree chamfers are to be provided in accordance with Fig 5.1

[NOTE: alternatively a purpose bull nosed arris trowel may be used to leave the new joint edge rounded off to a radius not greater than 5 mm].

5.20 CONSTRUCTION JOINTS

5.20.1 Construction joints shall be simple butt joints as shown in Figure 5.2. They shall be vertical and straight. The pavement surface across the joints shall be finished to give the regularity specified in Clause 5.27.2. A 5 mm 45 degree chamfer or a 5 mm bull nose is to be incorporated.

5.20.2 The longitudinal construction joints shall be made against the forms specified in Clause 5.12, or against the travelling forms or conforming plate of a slip-form paving machine, and against previously laid concrete as the laying of the concrete proceeds.

5.20.3 At the end of a day's work or when mixing stops such that the requirements of Clause 5.24.1 cannot be adhered to, transverse construction joints shall be made. They shall be constructed against forms and shall take the place of contraction grooves specified in Clause 5.26.

5.20.4 A purpose-made bull nosed arrising trowel shall be the final tool to be drawn, lightly and carefully, along the edge of the concrete, between it and the forms where fixed forms are being used, to leave it rounded-off to a radius not exceeding 5 mm. The surface texture, specified in Clause 5.21 shall extend to the edge of the 5 mm arris.

5.20.5 Fixed forms shall be removed without damaging the concrete, particularly the rounded arris. Any minor surface cavities exposed shall immediately be filled with mortar composed of 1 part of cement to 2 parts of fine aggregate. The exposed vertical face shall then be painted or sprayed with a uniform coating of bitumen emulsion as specified in Clause 3.11 for initial curing.

5.20.6 When a lane of concrete has been placed by slip-form paver, before an adjacent lane is laid against it the straightness of the vertical edges of the lane shall be checked using a 1 m long straightedge. Any deviations in excess of 5 mm beneath the straightedge shall be corrected by grinding, or by other means acceptable to the Project Manager. Any concrete which may have escaped beneath the side forms of the paver shall be trimmed back to achieve the same straightedge tolerance. Any minor surface cavities exposed shall be filled with mortar composed of 1 part of cement to 2 parts of fine aggregate. The exposed vertical face shall then be painted or sprayed with a uniform coating of bitumen emulsion as specified in Clause 3.11, as a bond-breaker, before the adjacent concrete is placed.

5.20.7 Where concrete is to be placed against hardened concrete laid under this Contract, the exposed edge of the hardened concrete shall be examined immediately before laying begins. Any cracks which have been induced in the hardened concrete by the contraction grooves shall be noted and taped over to prevent ingress of grout from the fresh concrete. In addition, contraction grooves which are found to have induced cracks shall be sealed temporarily by use of paper cord or other approved means to prevent ingress into the cracks of slurry created when grooves in the new slab are sawn. The cord and any slurry, grout or other materials in the grooves shall be removed before the pavement is considered complete.

5.20.8 When the slab on the second side of a construction joint is laid, a purpose-made bull nosed arrising trowel shall again be the final tool to be drawn, lightly and carefully, along the edge of the slab to produce an arris of 5 mm maximum radius to match that on the first side.

5.21 TEXTURING OF SURFACE

5.21.1 After surface blemishes have been eliminated with scraping straightedges, as specified in Clause 5.17, or longitudinal finisher, as specified in Clause 5.18, and before the application of the curing liquid for initial curing as specified in Clause 5.25, the surface of the concrete shall be textured as detailed below:

- *Runways and High Speed Turn-offs*.
  While the concrete is still soft enough to take an impression, a wire comb shall be drawn, mechanically or by hand, from a bridge platform spanning the lane, across the surface at right angles to the slab edges. Care shall be taken not to damage the arrises on joints during this operation. The texture produced shall satisfy the texture depth test requirements specified in Clause 5.27.3.
- *All other external surfaces except aircraft washdowns*.
  While the concrete is still soft enough to take an impression, a broom with medium coarse fibres shall be drawn, mechanically or by hand, from a bridge platform spanning the lane, lightly across the surface at right angles to the slab edge. Care shall be taken not to damage the joint arrises during this operation.
- *Hangar Floors*.
  The surface shall receive no texturing treatment. Following the use of the scraping straightedge or longitudinal finisher, steel floats may be used to the minimum extent necessary to remove minor blemishes. If a proprietary finish for a floor is shown on the drawings, the manufacturer's instructions on finishing and texturing the concrete shall be followed.

5.21.2 If it is proposed to use a slip-form paving train to spread, compact and finish the concrete, in accordance with Clause 5.18, the Contractor shall confirm with his tender that the requirements of Clause 5.21.1, as appropriate, can be complied with. Alternatively, detailed proposals for other methods giving equivalent surface textures shall be submitted. If the Contractor's proposals are considered satisfactory in principle, a qualified preliminary acceptance of the methods will be given by the Project Manager prior to the letting of the contract. Final approval to the methods shall rest with the Project Manager on the basis of assessment during and after the laying of the trial areas specified in Clause 6.2. General laying of concrete shall not begin until final approval has been obtained.

5.22 FINISHED LEVELS AND SURFACE REGULARITY

5.22.1 The finished surface levels shall conform with the levels, profiles and contours shown on the drawings subject to the requirements of Clause 5.6. Where the Project Manager so directs, deviations from the required levels exceeding 6 mm shall be corrected by cutting out and replacing the concrete in the offending area by the means specified in Clause 5.32. Where the Project Manager is satisfied that the permitted deviation is exceeded only at a local high spot, correction by an approved grinding method and/or grooving as specified in Clause 5.34 will be permitted.

5.22.2 The surface regularity of the finished concrete shall satisfy the Straightedge Test requirements specified in Clause 5.27.2.

5.23 INITIAL CURING

5.23.1 Immediately after the surface of the compacted concrete has been textured in accordance with Clause 5.21, initial curing of the exposed concrete surfaces shall begin with the application of the approved compound specified in Clause 3.10. The curing compound shall be handled and applied strictly in accordance with the manufacturer's instructions. Each container of curing compound shall be agitated vigorously immediately prior to use to ensure full dispersal of the flake aluminium within the compound. The compound shall be sprayed on at a uniform rate of spread which shall be sufficient to obtain a complete coverage of the surface and shall be at least equal to that specified by the manufacturer on the consignment certificate. After application, the compound shall give a continuous film of uniform thickness with an unbroken metallic finish, free from pinholes or other imperfections, over the entire surface of the concrete.

5.23.2 When the concrete has been laid by means of a slip-form paving machine, in accordance with Clause 5.18 the compound shall be applied by a mechanical sprayer. This shall be arranged to span the lane and spray while travelling longitudinally. The compound shall be continuously agitated and mixed in its container during mechanical spraying. The nozzles shall be arranged in a manner which will ensure a uniform coverage, free of streaks and lines, and shall be protected by an efficient shield to prevent wind-blown losses.

5.23.3 Hand operated spraying equipment shall be held on site to complete the spraying of concrete already laid in case of temporary breakdown of the mechanical sprayer. In this event, further concreting shall cease until the Contractor provides an efficiently operating mechanical sprayer to the satisfaction of the Project Manager. When the concrete has been laid by semi-mechanised means in accordance with Clause 5.17, or by hand, the use of hand operated spraying equipment will be permitted for all of the work.

5.23.4 Immediately after removal of forms, exposed vertical edges shall be painted or sprayed with the bitumen emulsion specified in Clause 3.11.

5.23.5 When a floor hardener is specified, no curing compound shall be used. If a proprietary floor treatment is shown on the drawings, the manufacturer's instructions on initial curing shall be followed.

5.24 TIME ALLOWED FOR CONCRETING

5.24.1 The total time taken from the addition of water to the concrete mixture to the finishing of the slab, including application of the initial curing membrane, shall not exceed 90 minutes. With his tender, the contractor shall provide a method statement showing how compliance with this clause can be achieved with the equipment proposed for use. The statement shall include details of the sequence of operations commencing with addition of water at the mixer and finishing with texturing of the concrete surface giving estimated times for each operation and an estimated overall time. The estimates given shall be verified during the laying of the trial areas specified in Clause 6.2.

[NOTE: Further information on maximum working times is provided within Table 10/7 of Clause 1024 of HA SHW Series 1000. Where temperatures exceed 25 degrees and two layer work is involved a reduced 60 min period applies]

5.24.2 A record shall be kept by the Contractor of areas of concrete which fail to meet this requirement. The record shall be submitted daily to the Project Manager. Only a qualified acceptance of the concrete in these areas will be given and, if directed by the Project Manager, the Contractor shall cut out the concrete and replace it by the methods detailed in this Specification, at his own expense.

5.25 FINAL CURING

5.25.1 Following the initial curing specified in Clause 5.23, the concrete shall immediately be protected for a period of not less than 4 hours by covered frames spanning the lane. When the concrete is laid by the method specified in Clause 5.17 the frames shall be wheeled and shall travel on the rails on the forms specified in Clause 5.12. The, details of the frames, and how they will be moved shall be included with the statement returned with the tender in accordance with Clause 5.18.

5.25.2 The covering shall be of an approved opaque light coloured material. It shall be stretched over the top of the frame so that it is not less than 75 mm or more than 500 mm above the surface of the concrete. The sides and ends of the frames shall be panelled down to the surface level of the concrete. The frames shall be positioned to give complete coverage of the concrete.

5.25.3 Immediately the frames have moved forward after the 4 or 6 hour period, the concrete shall be completely covered with 0.075 mm polythene sheet laid directly on the surface and securely fixed. The coverage shall be maintained for at least 3 days, except when either frost insulation is necessary in accordance with Clause 5.8.1. All covered frames and sheeting shall be kept in good condition.

(NOTE: Guidance to Project Managers on final curing is given in Clause Z.11 of Appendix Z).

5.26 CONTRACTION GROOVES

5.26.1 Contraction grooves shall be as detailed in Figure 5.2. They shall be vertical and straight. Their depth from the surface of the slab shall be between one fifth and one quarter of the actual slab thickness.

5.26.2 The grooves shall be sawn to a maximum width of 3 mm. The grooves shall be sawn as soon as the concrete has gained sufficient strength to prevent the surface being ripped or damaged by the operation. The Contractor shall ensure that random cracking due to late sawing does not occur and all sawing shall be completed within 18 hours of the concrete being finished. It shall be demonstrated on the trial areas specified in Clause 6.2 that the type of saw and blades proposed are suitable for the intended purpose on concrete with the particular ingredients being used. All sawn grooves shall be flushed out using a water pressure jet at the time of sawing and shall be kept clean and free of deleterious material.

5.26.3 If, at any time during the course of the work, the cutting of grooves fails to meet the time limit specified in Clause 5.26.2 or if cracking should occur before or during saw cutting, the placing of concrete shall cease until the difficulties have been resolved.

5.27 TESTS ON HARDENED CONCRETE

5.27.1 Depth, Voidage and Compressive Strength of Cores

5.27.1.1 In addition to the cores cut when cube tests fail (as specified in Clause 5.15.2.4), 150 mm diameter cores for routine examination and test shall be cut from the pavement slab approximately one third along the diagonals of bays. These cores shall be cut between 3 and 7 days after the concrete is laid. Each core with its core hole shall be numbered (consecutively as cut) and the number shall be marked clearly on core and pavement. The contractor shall produce record drawings detailing the location of all cores taken suitable for inclusion in the Operation and Maintenance Manual.

5.27.1.2 After removal, each core shall first be measured for diameter and length in accordance with BS EN 13863-3 and the saturated density shall be determined as per Clause 5.27.1.3. The core may be inspected by the Project Manager for comparison with a core cut from an approved trial area in accordance with Clause 6.2.5, in respect of honeycombing and visible voids.

5.27.1.3 The cores shall be prepared by trimming and capping or grinding each end for compression testing in accordance with the requirements of BS EN 12504-1. Each core shall be reduced in length by sawing off the top so that the lower section shall have a length /diameter ratio in the range 1.0 to 2.0 as recommended by BS EN 13877-2. The preferred length/diameter ratio is 1 to 1.2. The core shall then be stored in a curing tank in accordance with the requirements of BS EN 12390-1 before testing at (28 ± 3) days. The saturated density shall be determined in accordance with BS EN 12390-7 and the compressive strength determined in accordance with BS EN 12504-1. The corrected core strength of the concrete shall be calculated from the in situ core test strength multiplied by the appropriate length/diameter correction factor from Table 1 of BS EN 13877-2, which is reproduced as Table 5.3.
[NOTE: Preparation of cores with metal caps/internal caps to ASTM C1231/C 1231M criteria is permitted as an alternative to the BS EN method as it contributes to reduced preparation time]

TABLE 5.3 CORRECTION FACTORS FOR COMPRESSIVE STRENGTH OF CORES

Length/diameter ratio	Correction factor
1.00	1.00
1.25	1.07
1.50	1.12
1.75	1.16
2.00	1.18

5.27.1.4 For the first 500 m³ of routine production of Pavement Quality Concrete, one core shall be cut from each 150 m^2 of concrete laid or one per day's laying if this is less. Thereafter, the rate shall be one core per 300 m^2 laid or one per day. Each core and beam shall be taken from a location corresponding to a delivery of concrete sampled for cube testing in accordance with Clause 5.15.2.

5.27.1.5 Each core shall comply with all of the following four requirements:

(i) The total length of the core shall not be less than 5 mm of the design slab thickness shown on the Project drawing, or exceed it by more than 25 mm.
(ii) In the opinion of the Project Manager, the core shall compare favourably with the core obtained in accordance with Clause 6.2.5 in respect of honeycombing or voids.
(iii) The corrected core strength at (28 ± 3) days shall not be less than [32] (28) {25}*N/mm²

(iv) The density is a minimum of 97% of the job standard density obtained from the trials.

(*NOTE: The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and to delete the others).

5.27.1.6 If any core fails to satisfy any of the requirements of Clause 5.27.1.5, four additional cores shall be cut at 5 m spacings along the lane in positions symmetrical about the position of the failed core. All 4 new cores shall satisfy requirements (i) and (ii) in Clause 5.27.1.5. If the failure of the original core included lack of compliance with requirement (iii), the 4 new cores shall be prepared and tested for compressive strength in accordance with BS EN 12504-1 and using the correction in Table 5.3 at (35 ± 3) days. The mean 35 day corrected core strength value of the 4 cores shall be at least [38] (34) {29}* N/mm² and no more than one individual value shall be below [35] (30) {26}* N/mm². If either or both of these requirements and/or either or both of requirements (i) and (ii) of Clause 5.27.1.5 are not satisfied, the area of pavement slab represented by the 4 cores shall be condemned. The minimum area shall be taken as the 20 m length of the pavement lane symmetrical about the core positions. The extent of any further unacceptable concrete in each direction along the lane adjacent to the condemned area shall be investigated by cutting at 5 m spacing and testing additional groups of 4 cores until a group in each direction satisfies all of the requirements.

(*NOTE: The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and to delete the others).

5.27.1.7 The mean 28 day corrected core strength value for the set of routine cores representing the first 500 m^3 of normal production and for subsequent sets each representing 1000 m^3 of production (to correspond with sets of 7 day cube strength values specified in Clause 5.15.2.3) shall be not less than [43] (38) {34}* N/mm². If the mean value from any set of results falls below [43] (38) {34}* N/mm², either:

(i) the concrete mixture shall be adjusted to increase its strength, using the relationship between cube and core strengths obtained from this set of results to estimate the revised target mean 7 day cube strength value necessary, or,
(ii) if core densities indicate that compaction is inadequate, measures shall be taken to the satisfaction of the Project Manager to improve compaction. If the mean value from a set of results is below [38] (34) {29}* N/mm², work shall cease until the trial mixture and trial area procedures specified in Clauses 6.1 and 6.2 have been repeated. The area of pavement from which a set of cores fail to achieve a mean 28 day corrected core strength of [43] (38) {34}* N/mm² shall be condemned should the Project Manager so instruct.

(*NOTE: The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and to delete the others).

5.27.2 Surface Regularity

5.27.2.1 Tests for the surface regularity of the finished Pavement Quality Concrete shall be carried out using the method described in Appendix B as soon as possible commensurate with the curing regime,.

5.27.2.2 The following minimum number of tests shall be made on each lane:

- one test at each longitudinal construction or expansion joint, with test alignment normal to the joint, for each 10 m of such joint. The straightedge shall be positioned with 2 m of its length on the test lane and 1 m on the adjacent lane. When the adjacent lane has yet to be laid, the straightedge shall be positioned with one end on the joint line. [NOTE :alternatively this may be left until the next adjacent bay is laid, however the earlier that the measurements are taken the more immediate the rectification can be achieved]

- two tests across each transverse construction or expansion joint, with test alignment normal to the joint.
- two tests on the interior of the lane, one test aligned normal to and one parallel to the longitudinal joints, for each 50 m^2 of surface laid. The positions for test shall be selected by the Project Manager and the testing shall be carried out in his presence.

5.27.2.3 The finished surface should be free from excessive high spots or depressions which may endanger the manoeuvrability of aircraft or vehicles or give rise to ponding of surface water. The constructed pavement levels should not deviate by more than ±6 mm from design levels. Stepping in excess of 5 mm across concrete joints is to be avoided and no depression under a 3m straight edge should be greater than 3 mm subject to the requirement to avoid ponding. The clearance beneath the straightedge between points of contact with the surface during test or the calculated height of any highspot shall not exceed 3 mm in tests at longitudinal joints or 3 mm in other test positions.

5.27.2.4 Points on the surface which fail to comply with this requirement shall be marked and the following action taken:

- At each failure position at a longitudinal joint, ten further tests, five in each direction, shall be made at 1 m intervals along the lane. If more than two of these additional tests also fail, or if in any test, including the initial one, clearance beneath the straightedge between points of contact with the surface or calculated height of any highspot exceeds 7mm, the length of the lane of concrete bounding the failure positions shall be condemned.
- At each failure position on a transverse construction or expansion joint, further tests shall be taken at 1 m intervals along the whole length of joint to determine the extent of the deficiency. Correction by an approved grinding method and/or grooving as specified in Clause 5.34 may be allowed but, if this is not feasible, one or both of the bays of concrete adjoining the joint shall be condemned.
- At each failure position on the interior of a lane, the straightedge shall be used as directed by the Project Manager within the bay containing the failure to determine whether the failure is due to an isolated high spot. Isolated high spots may be corrected by an approved grinding method and/or grooving as specified in Clause 5.34. Bays containing more than one high spot or one or more depressions which will cause water to pond shall be condemned.

5.27.2.5 If the surface regularity on two successive days' work fails to satisfy the specified test requirement, all concreting work shall stop until the spreading, compacting and finishing operations have been checked and the cause of failure established and corrections have been made, to the satisfaction of the Project Manager.

5.27.3 Surface Texture

5.27.3.1 Where a surface texture is required, it shall be measured, using volumetric patch tests as described in BS EN 13036-1, as soon as possible and normally not more than 4 days after laying, subject to dictates of the curing and protection regime in place.

5.27.3.2 Three sets of 5 tests shall be made with a frequency of one set along each lane of concrete for each 150 m length laid, or a minimum of one set for each day's work when this is less. The locations for test shall be selected by the Project Manager.

5.27.3.3 The 5 positions for each set of tests shall be at the centre point of each quarter of the bay on a diagonal line drawn between opposite corners of the bay and at the intersection point of the diagonals.

5.27.3.4 For runways, short takeoff and landing (STOL) strips, concrete dummy deck facilities and fast exit taxiways, the average mean texture depth (MTD) for each set of tests shall not be less than 0.85 mm or greater than 1.1 mm. Not more than one test of each set shall show a MTD less than 0.75 mm or greater than 1.2 mm. For taxiways, turnpads and hardstandings, the average MTD for each set of tests shall not be less than 0.50 mm and not more than one test of each set shall show a MTD less than 0.35 mm.

5.27.3.5 When compliance with the minimum MTD requirement is not achieved, the deficiencies shall, as directed by the Project Manager, be broken out and replaced as specified in Clause 5.32 or made good by transverse grooving by the method specified in Clause 5.34.

5.27.3.6 When compliance with the maximum MTD requirement is not achieved, the contractor may submit proposals to the Project Manager for remedial actions to reduce the MTD to acceptable levels. Where the proposals are not accepted or the required MTD cannot subsequently be achieved, the deficiencies shall be broken out and replaced as specified in Clause 5.32.

(NOTE: Determination of mean texture depth by laser texture meter as described in Parts 2 and 3 of BS ISO 13473 will be permitted, subject to calibration on the pavements concerned against the volumetric patch method described in BS EN 13036-1.)

5.27.4 Surface Finish, Blemishes and Defects*

(*NOTE: The aim of the concrete placing operations specified in Clauses 5.17 and 5.18 is to produce a durable finished concrete surface, textured where required, that is free of surface defects and blemishes and that achieves the functional requirements given in Clause 1.2

[NOTE: Britpave Guidance Note 4: Rigid Airfield Pavements Surface Finish and Regularity and Texture provides further information and photographs of defects].

5.27.4.1 Overworking of the concrete surface by the use of hand floats and/or application of additional water in order to smooth out surface defects is not permitted.

5.27.4.2 Regardless of extent and severity, constant occurrence of surface defects, particularly in consecutively laid bays, is an indication of problems in the concrete mix and/or laying, compaction and finishing processes. At the discretion of the Project Manager, concrete operations shall be suspended until the mix design and laying processes have been reviewed and supplementary trial areas undertaken in accordance with Clauses 6.1 and 6.2, if required.

5.27.4.3 Subject to the provisions of Clause 5.27.4.2 and with the agreement of the Project Manager:

- Small surface voids/defects, up to 4 mm diameter/depth may be acceptable provided that the total area in any bay, when aggregated together, does not exceed 450 mm^2 and that the voids/defects are not concentrated in localised areas of the bay.
- Larger surface voids/defects, up to 10mm diameter/depth may be acceptable provided that the total area in any bay, when aggregated together, does not exceed 750 mm2 and that the voids/defects are not generally concentrated in localised areas of the bay.
- Surface voids/defects greater than 10 mm in diameter/depth may be treated by coring out and reinstating the core hole in accordance with Clause 5.31, provided that the total area of reinstatement in any bay, when aggregated together, does not exceed 0.06 m2. The maximum size of core permitted shall be 150 mm diameter and no core shall be permitted within a distance of three core diameters of any joint, bay edge or adjacent core location.

5.27.4.4 Where the degree of surface voids/defects in a bay exceeds the limits given in Clause 5.27.4.3, the affected bay(s) shall be broken out and replaced in accordance with Clause 5.32.

5.27.4.5 Crazing, sometimes referred to as cobweb or chicken wire cracking, is usually associated with poor curing and /or excessive laitence. Acceptability is dependant upon the extent and severity of the cracking and whether the cracking is occurring in a sound concrete matrix or in a thick layer of laitence or mortar. Deep cracks in a thick layer of laitence are unacceptable and the affected bay(s) shall be broken out and replaced in accordance with Clause 5.32.

5.27.4.6 Plastic cracking is not acceptable and the affected bay(s) shall be broken out and replaced in accordance with Clause 5.32. [NOTE: This defect is related to tensile failure and a cause may be late saw cutting or the surface drying out. Investigative coring is usually undertaken to verify the cause of this major defect.]

5.28 SEALING OF EXPANSION JOINTS

5.28.1 Wire brushes shall be used to remove the top of the filler in the expansion joints specified in Clause 5.19 to produce joint sealing slots which can be sealed to the dimensions shown in Figure 5.1. Ploughs shall not be used for removing the filler.

5.28.2 The exposed inside faces of the concrete along these sealing slots shall be grit blasted until all loose fractions have been dislodged. Care to be taken to ensure that arrises are not damaged. [NOTE: care should be taken to ensure this is a recyclable process and that capture of grit blast material takes place without impairing future joint function or creating FOD issues].

5.28.3 Each joint shall then be inspected to ensure that the filler is exposed for the whole length of the joint and that concrete does not intrude into gaps between or at the ends of lengths of filler board. Any deficiency shall be corrected with concrete saws, with blades suitably set to cut the full width and, if necessary, the full depth of the joint.

5.28.4 Each joint shall be prepared in accordance with the methods described in Clauses 4.1 and 4.2.2 to 4.2.5 inclusively of BS 2499: Part 2 (for hot applied joint sealing compound) or BS 5212: Part 2 (for cold applied joint sealing compound). Additional joint filler and/or bond breaker tape shall be placed in accordance with Clause 4.3 of BS 2499: Part 2 or BS 5212: Part 2.

5.28.5 Each joint shall then be primed in accordance with the methods described in Clause 4.4 of BS 2499: Part 2 or Clause 5 of BS 5212: Part 2. The primer shall be as specified in Clause 3.12 of this Specification.

5.28.6 The joint sealing compound specified in Clause 3.12 of this Specification shall be applied in accordance with the methods described in Clause 5 of BS 2499: Part 2 or Clause 2 of BS 5212: Part 2. Any overflow or spillage onto the surface of the concrete shall be removed.

5.28.7 Site testing shall be carried out in accordance with Clause 6 of BS 2499: Part 2 or Clause 7 of BS 5212: Part 2.

5.29 SEALING OF CONSTRUCTION JOINTS AND CONTRACTION GROOVES

5.29.1 Where shown on the drawings, construction joints and contraction grooves shall be unsealed.

5.29.2 Where shown on the drawings, construction joints and contraction grooves shall be widened, prepared and sealed as specified in Clauses 5.29.3 and 5.29.4 and detailed in Figure 5.2.

5.29.3 After removal of the polythene sheeting used for curing as specified in Clause 5.25.3, concrete saws with diamond tipped blades shall be used to form slots for sealing at the tops of construction joints and contraction grooves. Each slot shall be 13 mm (+3, -0 mm) wide and shall be of sufficient depth to allow a minimum sealant depth of 15 mm for cold applied or 20 mm for hot applied sealing compound (or the minimum sealant depth specified by the manufacturer, if this is greater) with the top of the seal finished 5 mm ± 2 mm below the pavement surface. An accurate method of guidance approved by the Project Manager on the basis of its performance on the trial areas specified in Clause 6.2 shall be used to ensure that the edges of the slots are parallel and straight.

5.29.4 Each slot shall be prepared for sealing in the manner specified for expansion joints in Clause 5.28.4. In contraction grooves, the top of the groove below each slot shall then be plugged with closed cell polyethylene foam or inert caulking cord. If recommended by the manufacturer of the sealing compound, a bond breaking tape shall be placed at the base of each slot. The slots shall then be primed and sealed in the manner specified for expansion joints in Clauses 5.28.5 and 5.28.6.

5.29.5 Site testing shall be carried out in accordance with Clause 6 of BS 2499: Part 2 or Clause 7 of BS 5212: Part 2.

(NOTE: Guidance for Project Managers on sealing construction joints and contraction grooves is given in Clause Z.10 of Appendix Z).

5.30 TRAFFIC ON FINISHED CONCRETE

5.30.1 Except for the saws required to comply with Clause 5.26 and the coring rigs required to comply with Clauses 5.27.1.1 and 6.2.5, the concrete shall not be subjected to traffic or other loads for at least 7 days after laying. Then, and only subject to the approval of the Project Manager, the concrete shall be used by the minimum of equipment essential for continuing the work. Traffic shall only run on the new concrete when no other means of access is possible to areas being laid later,

[NOTE: Britpave Publication BP01 “Concreting Pavements in Winter” January 2012 provides further detailed guidance .With regard to early age protection 2N/mm^2 is to be achieved before the protection is removed. It may therefore be feasible to demonstrate to the satisfaction of the Project Manager that this period can be reduced slightly].

5.30.2 Metal wheels shall not be allowed to run on the new concrete at any time. The flanged wheels used on spreading, compacting and finishing equipment when running on the form rails shall be replaced by rubber tyred wheels when they are run on the concrete and the crawler tracks of slip-form pavers shall be fitted with neoprene pads.

5.30.3 Protection of the finished concrete shall be the responsibility of the Contractor. Precautions shall be taken to prevent damage to the edges, marking of the surface or chipping of the joint or groove arrises. Any damage or defacement shall be made good by the methods and to the standards of this Specification.

5.31 FILLING CORE HOLES

Holes from which test cores have been taken shall be filled within 24 hours of cutting either with the approved Pavement Quality Concrete mixture or with concrete complying with the requirements of Section 7 of this Specification. The concrete shall be tamped in separate lifts of not more than 100 mm. The surface shall be finished flush with the adjacent concrete and with a texture to match it.

5.32 CUTTING OUT AND REPLACING CONCRETE

5.32.1 New Pavement Quality Concrete which has been condemned by the Project Manager shall be removed within three days of the Contractor being notified of the condemnation.

5.32.2 When the concrete is cut out, it shall be removed for the full depth of the slab. The area to be cut out shall extend across the full width of the lane between longitudinal construction joints. When the concrete bays are less than 4.5 m square, or equivalent area, or have an irregular shape as defined in Clause 5.7, the whole bay shall be removed. When the bays are 4.5 m square or larger, a half bay only may be removed, providing the half bay which will remain is free of defects. The whole bay shall be “quartered” by saw cut contraction grooves at the midpoint of the remaining half bay and the new half bay. No saw cut shall extend to the adjoining bay. The use of half bay replacements shall be restricted to outer and/or less-heavily trafficked areas.

5.32.3 The bay or section to be removed shall be defined on three or four sides by expansion or construction joints or contraction grooves. When only three sides are so defined, the additional side shall be marked out by a straight saw cut at least 40 mm deep. The leg of a length of rolled steel angle, wrapped in hessian or other shock absorbing material, shall be carefully tamped into this new saw cut and into existing contraction grooves to cover and protect the arrises of adjoining concrete during drilling and breaking out. A rotary percussion drill with cruciform bit shall be used to drill a row of full depth holes at 75 mm centres within the area to be removed adjacent to the new saw cut and each existing contraction groove. The bay or section shall then be broken out with care, beginning by use of percussion chisels or feather wedges to remove the concrete between the drill holes. The exposed edges of the adjoining bays or sections shall be trimmed to vertical and reasonably fair faces.

5.32.4 With the approval of the Project Manager, full depth saw cuts may be used instead of the drilling and wedging specified in Clause 5.32.3. No saw cut shall extend to the adjoining bay.

5.32.5 The edges of the concrete slabs adjacent to the area cut out shall be examined when removal and trimming have been completed. If damage or fractures are discovered, an additional area of concrete shall be cut out by the means specified in this Clause until only sound concrete remains.

5.32.6 Before replacing the concrete, the separation layer and the joint filler board in any expansion joints present shall be replaced. Pavement Quality Concrete shall then be laid, in accordance with the requirements of this Specification, to replace that removed.

5.33 CRACKS IN NEW CONCRETE

New concrete which has cracked, has blemishes or defects, and caused by late saw cutting referred to in clauses 5.27.4.4 to 5.27.4.6 shall be cut out and replaced by the means specified in Clause 5.32.

5.34 GROOVING OF HARDENED CONCRETE

5.34.1 All areas to be grooved shall be treated transversely by a single pass of a cutting drum incorporating 4 mm diamond saw blades at 25 mm centres. The drum shall be set to give a uniform 4 mm depth of grooving over the whole surface. Grooving operations shall not commence within 7 days after laying.

5.34.2 The surface of the concrete shall be grooved across the pavement at right angles to the pavement edges with grooves that follow across the pavement in a continuous line without a break. Grooving must not be undertaken within 50 mm of any parallel transverse contraction groove, construction joint, expansion joint or junction with bituminous surfacing.

5.34.3 The machine for grooving shall be a sawing machine incorporating a minimum of 12 No blades and an automatic guidance system to ensure that the spacing between peripheral grooves on successive passes remain constant. The contractor shall provide details of the machine proposed to the Project Manager prior to undertaking any grooving taking place.

5.34.4 Prior to commencing work, the contractor shall carry out a trial on an area of disused pavement selected by the Project Manager to prove the suitability of the sawing and cleaning equipment. Grooving works must not take place until approval of the trial has been given.

5.34.5 At all times during cutting, a high pressure water and vacuum extraction cleaning machine shall be in attendance to pick up the detritus arising, whether wet or dry, as soon as possible after the grooving machine has passed. The work area shall be left in a clean condition free of all loose material and of wet or dry slurry. Care shall be taken not to wash slurry into the drainage system.

5.35 TREATMENT OF SURFACE OF AIRCRAFT HANGAR FLOORS

All surfaces shall be clean and dry before treatment. After completion of final curing in accordance with Clause 5.26, the hangar floor shall be treated with

*either**

an approved proprietary floor hardener, guaranteed by the makers to produce a hard dense concrete surface with high abrasion resistance, impervious to the penetration of oils. The approved floor hardener shall be used strictly in accordance with the manufacturer's instructions.

*or**

two dressings of sodium silicate solution complying with BS 3984. The sodium silicate shall be to an approved Grade P84 or equivalent. The first dressing shall be a solution composed of one part of sodium silicate to four parts of water by volume. The second dressing shall be a solution composed of one part of sodium silicate to three parts of water by volume. The solution shall be sprayed over the floor and spread evenly with a mop or soft brush, any excess being wiped off, and the floor allowed to dry for at least 24 hours after each dressing. After the final drying, the floors shall be washed with clean water to remove any unabsorbed silicate.

(*NOTE: The Project Manager to delete the alternative not applicable for a particular specification).

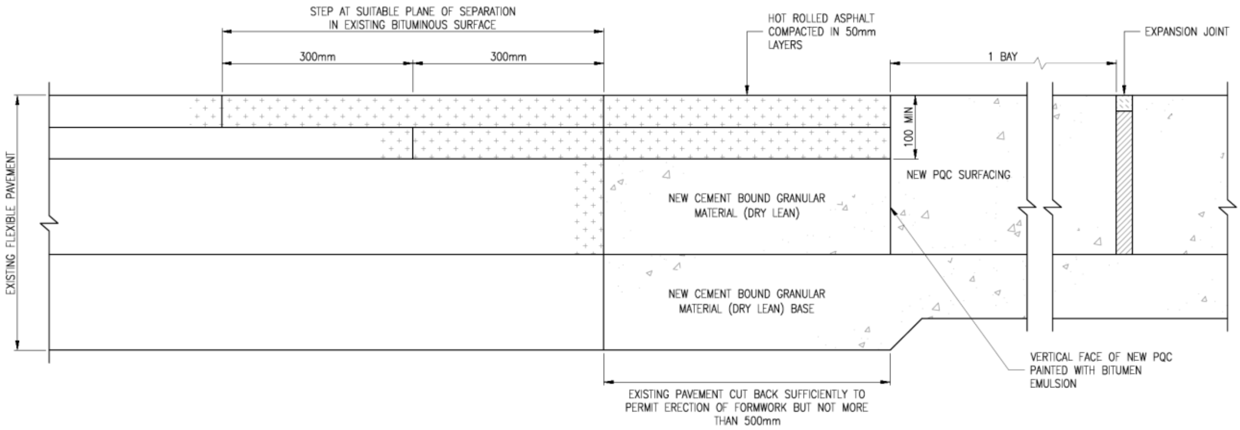
NOTE:

1. Technical Report 34 Concrete Industrial Ground Floors - 4th Edition Concrete Society gives extensive guidance on floor surface requirements and level tolerances for ground floors intended for specialist uses e.g. warehouse racking, mechanical handling equipment, slip resistance, etc.

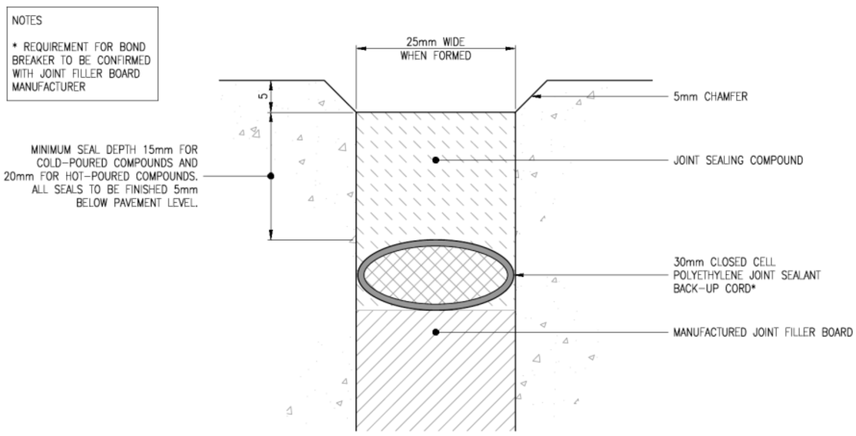
2. The expectations for the hangar floor are to be provided in the job specific statement of requirement and consideration be given to all future uses

3. In all instances the expected aircraft jacking or other loads are to be provided to ensure that the slab is adequately designed.

4. If proprietary floor hardeners are to be used the curing regime (type and timing) usually requires amendment. Reference should be made to product manufacturers' recommendations and requirements.



JOINT BETWEEN NEW PQC AND EXISTING BITUMINOUS SURFACING



EXPANSION JOINT

FIGURE 5.1: Details of Joints (Sheet 1)

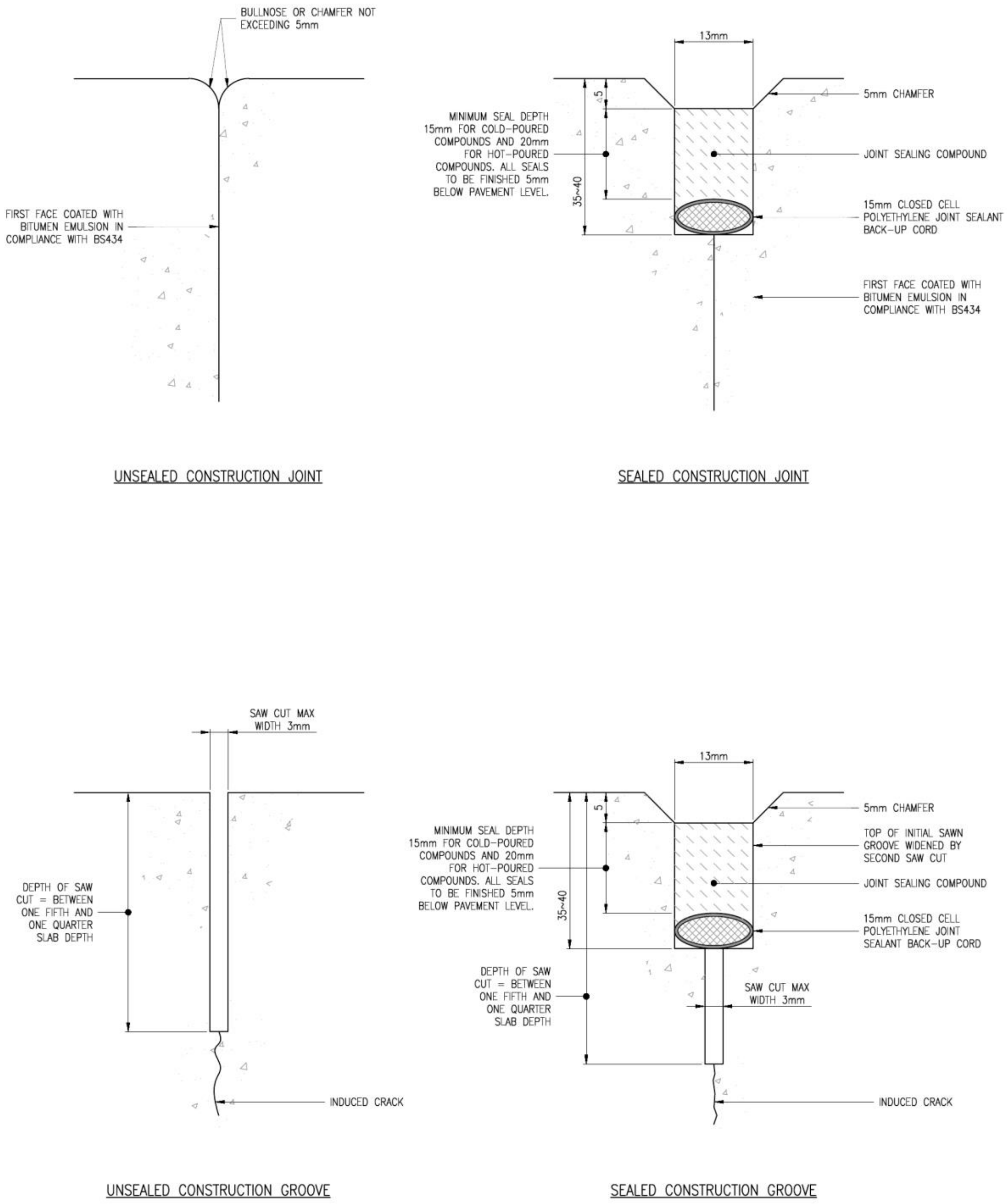


FIGURE 5.2: Details of Joints (Sheet 2)

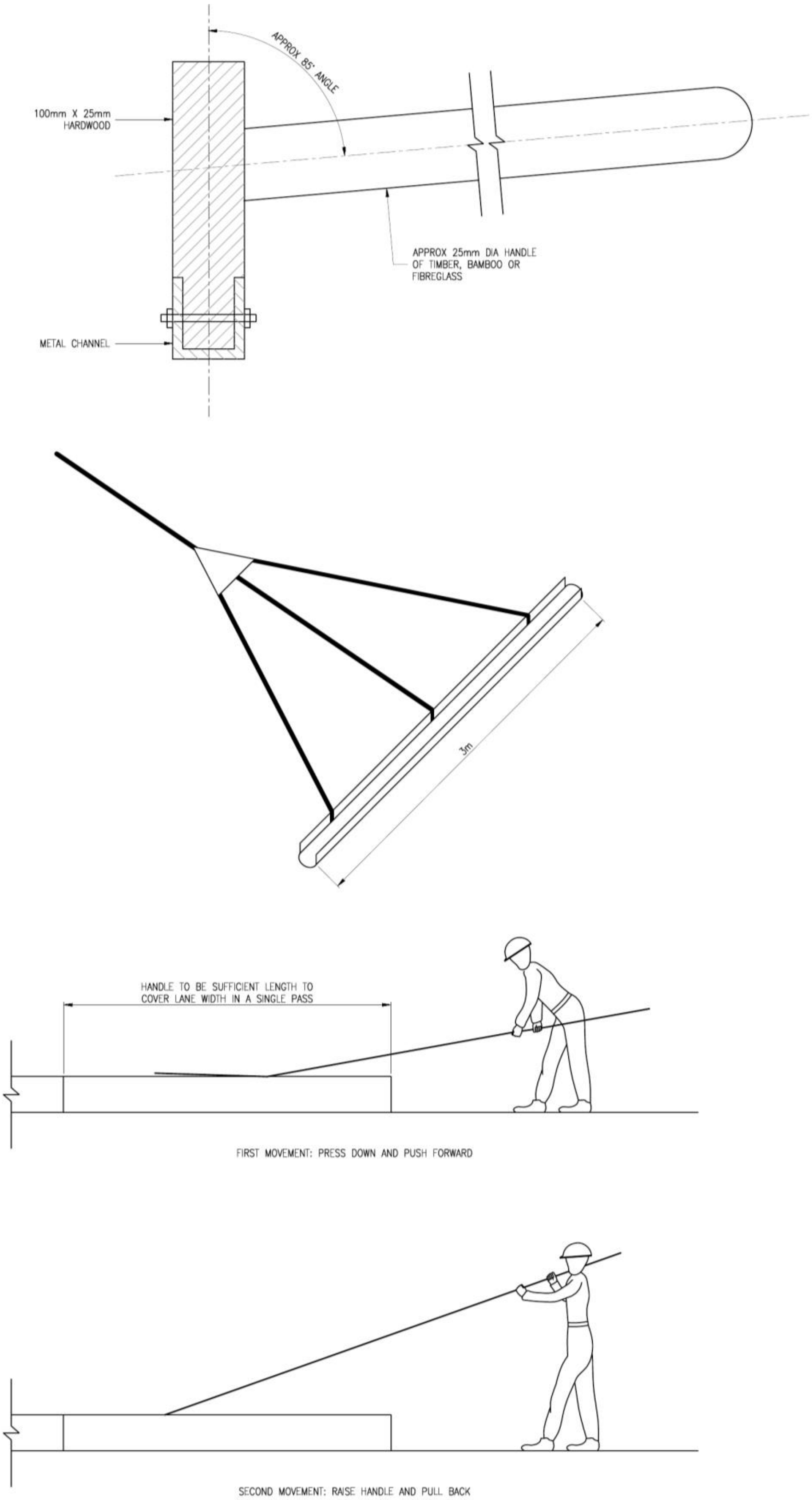


FIGURE 5.3: Scraping Straightedge

6 Trials

6.1 TRIAL MIXTURES

6.1.1 Trial mixes of the concrete mixture proposed to meet the design requirements for Pavement Quality Concrete specified in Section 4 shall be prepared in the approved mixer using the approved materials. The time at which the trial mixing will begin shall be advised to the Project Manager on the previous working day.

6.1.2 For each mixture proposed, a set of three pairs of 100mm (or 150mm) cubes from at least four separate batches shall be made, cured and tested at 7 days in accordance with Parts 1, 2 and 3 of BS EN 12390. The mean of the two results from each pair shall be taken as a test result. When the difference between a pair of results divided by their mean exceeds 15%, the test result shall be deemed invalid and shall be excluded from the assessment. If less than 9 valid results remain, the trial shall be repeated. The mean strength of all the valid results shall not be less than [45] (40) {35}* N/mm², or whatever higher value the Contractor considers necessary to ensure compliance with the requirements of Clause 4.6.1.

(*NOTES:

1. The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and to delete the others).

2. 150 mm cubes are required for 40 mm aggregate

6.1.3 If the test results fail to satisfy these requirements, the trial shall be repeated with adjustments made to the mixture until the test requirements are satisfied.

6.1.4 The proportions of the complying mixture(s) shall be reported to the Project Manager for his approval. The information provided shall include plots of the particle size distributions for the fractions of the combined aggregates retained on a 4.0 mm sieve and passing a 4.0 mm sieve, confirming compliance with the requirements of Clause 4.2. Concrete laying shall not begin until approval has been obtained.

6.2 TRIAL AREAS

6.2.1 Once the approval referred to in Clause 6.1.4 has been obtained, but not before, trial areas may be laid. Trial areas shall be laid along the edges of the pavement in positions approved by the Project Manager using the Pavement Quality Concrete mixture approved following the trial mix procedure specified in Clause 6.1. The trial areas shall be incorporated into the Works if they comply with the requirements of this Specification, but any trial area not complying with the requirements shall be broken out and replaced.

6.2.2 For concrete laid by the methods specified in Clause 5.18, each trial area shall be between 60 m and 200 m long and two lanes wide. For concrete laid by the methods specified in Clause 5.17, each area shall be between 30 m and 60 m long and two lanes wide. A separate area shall be laid for each of the mixtures it is proposed to use and for each of the thicknesses of concrete shown on the drawings. The concrete in the trial area(s) shall be spread, compacted and finished using the plant it is intended to use for the Works. Each area shall fulfil all of the requirements of the Specification and shall incorporate one of each type of joint and, unless agreed otherwise by the Project Manager, an area of each type of surface texture required in the Works. Where possible, the trial areas shall be laid at the maximum crossfall occurring in the Works.

6.2.3 A minimum of 12 pairs of 100 mm (or 150mm) cubes shall be made in accordance with Parts 1 and 2 of BS EN 12390 during the laying of each lane of a trial area. Each pair shall be from a sample taken in accordance with BS EN 12350-1 from a different delivery at the point of placing. The location in the pavement of each delivery sampled shall be recorded. The cubes shall be cured and tested for compressive strength in accordance with Parts 2 and 3 of BS EN 12390 at 7 days. The mean of the two results from each pair shall be taken as a test result. When the difference between a pair of results divided by their mean exceeds 15%, the test result shall be deemed invalid and shall be excluded from assessment of compliance. The mean of all the valid test results shall not be less than [45] (40) {35}* N/mm². No more than one result shall be below [34] (30) {26}* N/mm².

(*NOTE: The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and to delete the others).

6.2.4 A Compaction Index test in accordance with BS EN 12350-4 shall be made from each delivery sampled for cube testing. The mean Compaction Index value for all the results from a trial area shall be calculated. If the trial area is accepted, this mean value shall be taken as the job standard value for Compaction Index and the values measured in subsequent tests throughout the Works shall be within the tolerances given in Table 11 of BS EN 206.
[NOTE: As an alternative to using Compaction Index the Compacting Factor Test to BS 1881 Part 2 may be used.]

6.2.5 Between 3 and 7 days after the concrete in a trial area is placed, a diamond-tipped core cutter shall be used to cut at least six 150 mm diameter cores, as specified in BS EN 12504-1, from each lane of the trial area, from locations corresponding to deliveries of concrete sampled for cube testing. Each core shall be free of honeycombing and the top 40 mm of each core shall show no more than 10 voids with dimensions greater than 3 mm. At least ten of the cores shall then be cured, prepared and tested at (28 ± 3) days. The saturated densities of the cores shall be determined in accordance with BS EN 12390-7 and recorded. Corrected core strengths shall be determined as described in Clause 5.27.1.3

6.2.6 The mean corrected core strength value at (28 ± 3) days of all the cores taken from a trial area shall be at least [43] (38) (34}* N/mm² and no individual value shall be below [32] (28) {25}* N/mm². If this specified mean corrected core strength value from cores is not achieved, the mixture design procedure shall be repeated with a design target mean 7 day cube strength calculated to give at least the specified mean corrected core strength value from cores, using the relationship between mean values from cubes and cores established on the trial area. Trial mixtures and trial areas shall be repeated using this revised target mean 7 day cube strength value in place of the [45] (40) {35}* N/mm² specified in Clauses 6.1.2 and 6.2.3.

(*NOTE: The Project Manager to select the first, second or third value, corresponding with that selected in Clause 4.6.1, and to delete the others).

6.2.7 If in the opinion of the Project Manager, any of the trial areas fail to comply with any of the Specification requirements, revisions to the mixture or modifications to plant or working methods shall be made as the Contractor considers necessary to ensure future compliance. New trial areas shall be laid in accordance with this Clause. All of the failed areas shall be cut out.

6.2.8 Each trial area will be approved by the Project Manager that it has satisfied all of the specified requirements and shall then be clearly marked. General laying of Pavement Quality Concrete, other than further trial areas, shall not begin until approval has been obtained.

6.2.9 A written statement of the mixture proportions (by weight) and the job standard value of the Compaction Index or Compacting Factor (or slump for limited extent hand lay) of the concrete used in the approved trial area shall be provided to the Project Manager before general mixing and laying of Pavement Quality Concrete begins.

6.2.10 One of the cores cut from each of the approved trial areas shall be retained by the Contractor and another shall be retained by the Project Manager. Both shall be marked "Approved" and shall be exhibited throughout the Contract period as examples of the required standard. The approved section of each type of surface texture shall be identified. The standards of workmanship and finish, including degree of honeycombing, of all Pavement Quality Concrete included in the Contract shall be equal to that of the approved trial areas.

6.2.11 For flexural strength concrete F5 and above the strength relationship between beams, core and cubes is to be established .

Relevant production targets for all concretes are to be approved by the Project Manager prior to commencement of the main production.

[Note: For F4.5 and below this extension of beam testing is for research purposes and allows DIO, in liaison with industry, to establish relationships between cube, core, and flexural strengths. Routine flexural strength beam testing is already undertaken by industry. Summary test information regarding beams, cores and cubes is to be sent to DIO Airfield Pavements Section for collation]

7 Concrete for Surface Surrounds to Fittings

7.1 MIXTURE SPECIFICATION

The concrete mixture to be used for the surface surrounds to fittings such as lighting fittings, drainage gratings and frames, etc., shall be either a Pavement Quality Concrete mixture using a 4/20 mm coarse aggregate or a designed concrete to be supplied in accordance with the relevant clauses of BS EN 206-1, BS 8500-1 and BS 8500-2.

[NOTE: Use of cement additions using the PQC mix for the main works may not achieve the early strength required to protect the fittings, hence the CEMI requirement in the designed concrete below]

7.2 DESIGNED CONCRETE IN ACCORDANCE WITH BS EN 206-1

7.2.1 When a designed concrete in accordance with BS EN 206-1 is used, the specified requirements in accordance with Clause 11 of this BS EN shall be as follows:

(a) The concrete shall be Class C32/40.
(b) The concrete shall be suitable for use in exposure class XF4(UK).
(c) The maximum size of aggregate (D_{max}) shall be 20 mm.
(d) Coarse aggregate shall be crushed rock complying with BS EN 12620.
(e) Cement shall be Portland cement (CEM I) complying with BS EN 197-1.
(f) The minimum cement content shall be 325 kg per cubic metre of fully compacted concrete.
(g) The maximum free water/cement ratio shall be 0.55.
(h) Consistence (workability) shall be 'medium', with a nominal slump of 75 mm.
(i) The chloride content class shall be Cl 0.4.
(j) The Quality Assurance requirements described in Clause 2.4 of this Specification shall be satisfied.
(k) The concrete shall be placed by hand and compacted by poker vibrator.
(l) Every delivery shall be sampled for test.

7.2.2 Additional requirements shall be as follows:

(a) There are no special requirements for the cement.
(b) Neither ggbs nor pfa shall be allowed.
(c) The maximum Magnesium Sulphate Soundness Value of coarse aggregate and fine aggregate when determined in the manner described in Appendix A of this Specification shall be 18 for each source of supply and 30 for each fraction.
(d) Air entraining admixture complying with BS EN 934-2 shall be used. Water reducing admixture complying with BS EN 934-2 is permitted. No other admixture shall be used.
(e) There is no limit on maximum cement content.
(f) The reactive alkali content of the mix shall not exceed 3.25 kg/m^3 of Na_2O equivalent, using the declared mean alkali content of the cement in the assessment.
(g) The minimum total air content of the fresh fully compacted concrete shall be 3.5 %.
(h) The maximum/minimum temperatures of fresh concrete shall be as specified in BS 8500-2, Clause 5.4 and BS EN 206-1, Clause 5.2.8, respectively.
(i) There are no limits on maximum and minimum densities of the hardened concrete.
(j) The following information shall be provided by the concrete supplier to the Project Manager:
    - The nature and source of each constituent material, together with test or manufacturers' certificates showing compliance with specified requirements;
    - the source of supply of the concrete and any alternative sources;
    - the proposed proportions or quantities of each constituent per cubic metre of fully compacted concrete;
    - details of admixtures to be used;
    - evidence of the suitability of the proposed mix proportions to meet the specified requirements on strength , free water/cement ratio, chloride ion content and reactive alkali content;
    - results of all tests on concrete delivered to the works; and
    - certification of Quality Assurance.
(k) Sampling of the fresh uncompacted concrete shall be at the point of delivery into the construction and in accordance with BS EN 12350-1. Tests for consistence (slump),

air content of fresh concrete and compressive strength shall be carried out in accordance with Parts 2 and 7 of BS EN 12350 and BS EN 12390-3, respectively, and compliance judged in accordance with Table 11, Clause 5.4.3 and Annex B of BS EN 206-1, respectively. If requested, autographic records from the batching plants shall be made available for examination for assessment of compliance with minimum cement content and maximum water/cement ratio in accordance with Table 21 of BS EN 206-1.

(l) Copies of all delivery tickets, showing at least the minimum information required by BS EN 206-1 Clause 7.3, shall be passed to the Project Manager.

7.3 PREPARATION FOR CONCRETING

The surrounds to be concreted shall be prepared to the dimensions and in accordance with the details shown on the drawings. Extraneous material shall be removed and dust blown clear using oil-free compressed air immediately before concreting begins. Any forms shall be generously oiled to ease removal.

7.4 PLACING AND COMPACTION

The concrete shall be placed by a means which avoids segregation and contamination of the concrete with extraneous matter. The concrete shall be fully compacted using poker vibrators.

7.5 FINISHING

Unless the drawings show otherwise, the concrete surrounds shall be finished so that the clearance beneath a 3 m long test straightedge, as described in Appendix B, does not exceed 3 mm when the straightedge is placed anywhere on adjacent concrete paving so as to overlap onto the surround. Joints shall be finished in accordance with the details shown in Figures 5.1 and 5.2. Surface floating shall be kept to the minimum necessary to provide a smooth finish.

7.6 CURING

As soon as the surface of the surround has been finished, it shall be sprayed with the curing liquid specified in Clause 3.10.1 at the manufacturer's recommended rate of spread. After not more than 4 hours, the concrete shall be completely covered with polythene sheet as specified in Clause 5.25.3. This shall be kept in place and supplemented by frost insulation, if necessary, for at least 7 days.

8 Summary of Tests

8.1 TEST RESULTS

The contractor shall be responsible for having all testing carried out in accordance with the requirements of this Section and shall provide the Project/ Works Services Manager with a written copy of all results at the first reasonable opportunity but not later than 2 working days after completion of each test. Testing shall be started on specimens within 2 working days of sampling and shall be carried out in an expeditious manner.

8.2 TESTS FOR INITIAL APPROVAL OF MATERIALS

8.2.1 Before mixing starts and as part of the Quality Assurance requirements in Clauses 2.4, 3.1.2 and 3.1.3, the Contractor (or his materials supplier/s on his behalf) shall have carried out those tests required to determine the properties and grading of the aggregates for comparison with the relevant specification clauses as listed below:

- Coarse Aggregate (Clause 3.2).

Test	Reference
Sieve Analysis	BS EN 933-1
Soundness Value	Appendix A
Flakiness Index	BS EN 933-3
Resistance to Fragmentation (Los Angeles Coeff.)	BS EN 1097-2
Fines Content	BS EN 933-1
Chloride Content	BS EN 1744-1
Water Absorption	BS EN 1097-6
Shrinkage*	BS EN 1367-4
Magnetic Permeability*	—

(* Not always required – see Notes to Table 3.1)

- Fine aggregate (Clause 3.3).

Test	Reference
Sieve Analysis	BS EN 933-1
Soundness Value	Appendix A
Fines Content	BS EN 933-1
Magnetic Permeability*	—

(*Not always required – see Note to Table 3.2)

8.2.2 In addition, the Contractor shall submit the appropriate certificates for:

- cement (see Clause 3.4.4 and 3.4.5)
- fly ash (see Clause 3.4.7)
- ground granulated blast furnace slag (- see Clause 3.4.8)
- water (if necessary – see Clause 3.5.2)
- air entraining admixture (see Clause 3.6.2)
- other admixtures (see Clause 3.7.1)
- joint filler (see Clause 3.9.3)
- curing compound for exposed surfaces (see Clause 3.10.2)
- curing liquids for vertical faces (see Clause 3.11.2)
- joint sealing compound (see Clause 3.12.4)
- concrete for surface surrounds to fittings (see Clause 7.2.2 (j)).

8.3 ROUTINE TESTS ON BULK SUPPLIES THROUGHOUT PLANT MIXING

8.3.1 The Quality Assurance procedures for the supply of component materials shall include carrying out tests in order to check on the consistency of bulk supplies, to compare the properties and gradings of bulk supplies with the samples provided and to enable actions to be taken to cope with variations. The tests should include the following:

Test	Clause	Reference
Sieve analysis of aggregates	5.3.1	BS EN 933-1
Fines content of aggregates	5.3.2	BS EN 933-1
Chloride ion content in aggregates	5.3.3	BS EN 1744-1
Chloride ion (Qantab)		Table 3.2 note 3
Moisture content in aggregates	5.4.3	BS EN 1097-5

8.3.2 If the result of any test indicates that the bulk deliveries are not of a grading or quality consistent with the approved samples, the Contractor shall, at his own expense, carry out further tests to establish the location and extent to which the materials already stockpiled fail to meet the approved standard and, if stored on site, shall remove all material condemned by the Project Manager for this reason from the airfield.

8.4 ROUTINE TESTS ON PLANT THROUGHOUT PLANT MIXING

The Contractor shall arrange for checks on the calibration of weighing, water measuring and admixture dispensing mechanisms to be checked before mixing starts and at specified intervals during production (see Clause 5.5).

8.5 ROUTINE TESTS ON CONCRETE THROUGHOUT PLANT MIXING

As part of the Quality Assurance requirements specified in Clause 2.4, the Contractor shall carry out the following tests on concrete prepared for the works (including trials). The procedure shall ensure that the positions of concrete batches from which test samples are taken are fully traceable in the finished pavement.

Test	Clause	Reference
Degree of Compactability Compaction Index (CI) (or Compacting Factor Test)	5.15.1 and 6.2.4	BS EN 12350-4 (BS 1881:Part 103)
Slump	5.15.1,6.2.4 7.2.2k	BS EN 12350-2
Air content	5.15.3 and 7.2.2k	BS EN 12350-7
Cube strength	5.15.2, 6.1.2 and 6.2.3	BS EN 12390-3
Temperature (cold or hot weather only)	5.8.1 and 5.8.3	BS EN 206-1, Clause 5.2.9 and BS 8500-2, Clause 5.4

8.6 ROUTINE TESTS ON HARDENED CONCRETE

The Contractor shall undertake the series of tests on hardened concrete incorporated in the Works necessary to comply with the relevant specification clauses listed below:

Test	Clause	Reference
Corrected core strength	5.27.1, 6.2.5	BS EN 13877-2
Flexural strength Beam test	8.9	BS EN 12390-5
Concrete density	5.27.1, 6.2.5	BS EN 12390-7
Voids and honeycombing	5.27.1, 6.2.5	–
Slab thickness	5.27.1	BS EN 13863-3
Straightedge Test	5.27.2	Appendix B
Volumetric Patch Test	5.27.3	BS EN 13036-1
Joint seals	5.28.7, 5.29.5	BS 2499: Part 2 / BS 5212: Part 2

8.7 CERTIFICATES THROUGHOUT THE WORK

Throughout the course of the work, the Contractor shall submit certificates for all consignments of the following:

- cement (see Clauses 3.4.4 and 3.4.5)
- fly ash (see Clause 3.4.7)
- ground granulated blast furnace slag (see Clause 3.4.8)
- curing compounds for exposed surfaces (see Clause 3.10.3)
- curing liquids for vertical faces (see Clause 3.11.2)
- joint sealing compounds (see Clause 3.12.3).

8.8 ADDITIONAL TESTS ON MATERIALS

The Contractor shall arrange for check tests to be made on any of the materials for compliance with the appropriate clauses and the British Standard test requirements applicable to the clause if called upon to do so by the Project Manager either before mixing starts or at any time during the work.

8.9 BEAM TESTS

For flexural strength concrete the daily requirement is for beams (500mm sized) to be produced and referenced against cubes from the same concrete delivery. These are to be then tested at 7 & 28 days to ensure that the relationship between flexural strength, cube strength and core strength (as established via the laboratory testing and trials) holds firm.

Appendix A – Use of Magnesium Sulphate Test with Non-Standard Aggregate Fractions

A.1 SCOPE

This Appendix specifies a procedure extending the method in BS EN 1367-2 for assessing the soundness of aggregate when subjected to the cyclic action of immersion in magnesium sulphate, followed by oven drying, to all fractions.

A.2 APPARATUS AND REAGENTS

Apparatus and reagents as detailed in BS EN 1367-2, Clauses 6 and 7, (except that the balance for coarse aggregate, sub-Clause 6.2, to be accurate to 1 g) together with:

- 40 mm, 20 mm, 10 mm and 6.3 mm sized square hole perforated plate test sieves and 2 mm, 1 mm, 0.500 mm and 0.250 mm sized woven wire test sieves; the additional test sieves shall comply with BS EN 933-2; and
- at least two brass or stainless steel mesh baskets for immersing aggregate specimens for fractions other than 10 mm to 14 mm with the maximum dimension of the apertures not more than half the maximum aperture of the sieve on which the specimen is retained, but not less than 0.125 mm.

A.3 PREPARATION OF TEST PORTIONS

A.3.1 Bulk samples from each size of aggregate being delivered from each source of supply to be used shall be tested separately and the procedure described hereafter shall be applied to each separate sample.

A.3.2 Prepare two test portions from the bulk samples of each aggregate supplied as in BS EN 1367-2, Clauses 8.1 and 8.2, replacing "*minimum mass of 500 g of the 10 mm to 14 mm size*" in Clause 8.1 by the relevant masses from Tables A.1 and A.2.

A.4 PREPARATION OF FINE AGGREGATE TEST SPECIMENS FOR EACH FRACTION

A.4.1 The particle size distribution of the test portion shall be determined by the washing and sieving method described in BS EN 933-1 using the 10 mm, 6.3 mm, 2 mm, 1 mm, 0.500 mm and 0.250 mm sieves. The particle size distribution shall be recorded giving the percentage of the mass of the test portion retained between each pair of sieves, together with that passing the 0.250 mm sieve, to the nearest whole number.

A.4.2 The fraction passing the 0.250 mm sieve, together with those fractions retained whose proportions are less than 5% by mass of the test portion, shall be discarded. Nevertheless, the proportions that the discarded fractions represent shall be taken into account in the calculation of the test result.

A.4.3 One test specimen, of mass in accordance with Table A.1, shall be taken out of each fraction retained after completion of sub-Clause A.4.2. If there is insufficient material in any of these fractions to provide a test specimen of the required size, the procedure shall be repeated starting from sub-Clause A.3.2. The particle size distribution recorded shall be that obtained from all the material sieved out.

TABLE A.1 REQUIRED MASS OF FINE AGGREGATE TEST SPECIMENS

BS Sieves		Mass of specimen
Passing	**Retained**	**before test (g)**
10 mm	6.3 mm	300 + 10 / - 0
6.3 mm	2 mm	100 + 10 / - 0
2 mm	1 mm	100 + 10 / - 0
1 mm	0.500 mm	100 + 10 / - 0
0.500 mm	0.250 mm	100 + 10 / - 0

A.5 PREPARATION OF COARSE AGGREGATE TEST SPECIMENS FOR EACH FRACTION

A.5.1 The particle size distribution of the test portion shall be determined by the dry sieving method described in Clause 8.3 of BS EN 1367-2 using the 40 mm, 20 mm, 10 mm, 6.3 mm, 2 mm and 1 mm sieves. The fractions retained on the 20 mm sieve and passing the 1 mm sieve shall be discarded and not taken into account in the calculation of the test result. The remainder of the reduced sample shall be considered as the test portion. The particle size distribution shall be recorded giving the percentage of the mass of the test portion retained between each pair of sieves to the nearest whole number.

A.5.2 Those fractions retained whose proportions are less than 5% by mass of the test portion shall be discarded. Nevertheless, the proportions that the discarded fractions represent shall be taken into account in the calculation of the test result.

A.5.3 One test specimen, of mass in accordance with Table A.2, shall be taken out of each fraction retained after completion of sub-Clause A.5.2. If there is insufficient material in any of these fractions to provide a test specimen of the required size, the procedure shall be repeated starting from sub-Clause A.3.2. The particle size distribution recorded shall be that obtained from all the material sieved out.

TABLE A.2 REQUIRED MASS OF COARSE AGGREGATE TEST SPECIMENS

BS Sieves		Mass of specimen
Passing	**Retained**	**before test (g)**
40 mm	20 mm	1500 ± 50
20 mm	10 mm	1000 ± 10
10 mm	6.3 mm	300 + 10 / - 0
6.3 mm	2 mm	100 + 10 / - 0
2 mm	1 mm	100 + 10 / - 0

A.6 PROCEDURE

Procedure for each test specimen as in BS EN 1367-2, Clause 9, replacing "*10 mm sieve*" in Clause 9.6 by the sieve relevant to the lower size of the aggregate fraction.

A.7 CALCULATION AND EXPRESSION OF TEST RESULTS

A.7.1 Calculate the magnesium sulphate value of each test specimen as in BS EN 1367-2, Clause 10.1, replacing "*10 mm sieve*" by the sieve relevant to the lower size of the aggregate fraction.

A.7.2 Fractions not tested because they represent less than 5% by mass of the test portion shall be assumed to have a magnesium sulphate value equivalent to:

a) the mean of the magnesium sulphate value found by the tests on specimens of the two fractions immediately adjacent to it in size; or
b) the magnesium sulphate value found by the test on a specimen of the fraction, either larger or smaller, immediately adjacent to it if only one of these fractions were tested; or
c) the mean magnesium sulphate value found by the tests on specimens of the two fractions next but one adjacent to it if both these fractions were tested and the adjacent fractions were not; or
d) the magnesium sulphate value found by the test on a specimen of the fraction, either larger or smaller, in this order of priority, most nearly adjacent to it.

A.7.3 For samples of fine aggregate, the material passing the 0.250 mm sieve shall not be tested but shall be taken as having a magnesium sulphate value equivalent to that of the specimen passing the

0.500 mm sieve but retained on the 0.250 mm sieve.

A.7.4 The magnesium sulphate value of each test portion of aggregate shall be the sum of the magnesium sulphate values found for each aggregate fraction times the proportion by mass of that fraction in the test portion.

A.7.5 The magnesium sulphate value for the aggregate shall be the mean of the two results for the test portions to the nearest whole number. The magnesium sulphate value for each fraction of the aggregate shall be the mean of the magnesium sulphate values for the two results for the test specimens to one decimal place.

(NOTE. A suitable worksheet (with two examples, one fine aggregate and one coarse aggregate) is shown on the following pages.)

A.8 PRECISION

As in BS EN 1367-2, Annex A.

A.9 TEST REPORT

As in BS EN 1367-2, Clause 11, together with the magnesium sulphate value and the individual magnesium sulphate values of the two specimens for each aggregate fraction tested.

EXAMPLE A.1

Blackstone Quarry, 2/6.3 mm single size. Tested 8-25 February 2004						
Sieve Size		Grading of Test Portion (% of total mass)	Mass of Test Specimen		Magnesium Sulphate Value (% of original mass)	Weighted Mag. Sulphate value (%)
Passing (mm)	Retained (mm)		Before Test (g)	After Test (g)		
First Test Portion						
40	20	*0*	–	–	–	*0*
20	10	*0*	–	–	–	*0*
10	6.3	*26.4*	*303.2*	*278.2*	*8.2*	*2.18*
6.3	2	*69.4*	*104.9*	*98.6*	*6.0*	*4.17*
2	1	*4.2* (1)	–	–	*6.0* (2)	*0.25*
Total		*100*			Total	*6.60*
Second Test Portion						
40	20	*0*	–	–	–	*0*
20	10	*0*	–	–	–	*0*
10	6.3	*28.7*	*296.1*	*272.3*	*8.0*	*2.31*
6.3	2	*66.2*	*98.4*	*92.5*	*6.0*	*3.97*
2	1	*5.1*	*104.1*	*98.2*	*5.7*	*0.29*
Total		*100*			Total	*6.57*
					Mean	7

Notes: (1) Less than 5% by mass of total sample, no test specimen.
(2) Taken as equivalent to that for 6.3 mm to 2 mm size under sub-Clause A.7.2, indent (b).

EXAMPLE A.2

Sandy Heath Pit, Coarse Fine Aggregate. Tested 8-12 February 2004						
Sieve Size		Grading of Test Portion (% of total mass)	Mass of Test Specimen		Magnesium Sulphate Value (% of original mass)	Weighted Mag. Sulphate value (%)
Passing (mm)	Retained (mm)		Before Test (g)	After Test (g)		
First Test Portion						
10	6.3	*4.6 (1)*	–	–	*11.9 (2)*	*0.55*
6.3	2	*10.8*	*97.2*	*85.6*	*11.9*	*1.29*
2	1	*17.0*	*101.8*	*94.2*	*7.5*	*1.27*
1	0.500 mm	*25.2*	*92.9*	*89.0*	*4.2*	*1.06*
0.500 mm	0.250 mm	*26.2*	*104.1*	*99.3*	*4.6*	*1.21*
0.250 mm	–	*16.2*	–	–	*4.6 (3)*	*0.75*
Total		*100*			Total	*6.13*
Second Test Portion						
10	6.3	*4.4 (1)*	–	–	*11.2 (2)*	*0.49*
6.3	2	*10.9*	*104.1*	*92.4*	*11.2*	*1.23*
2	1	*17.3*	*106.8*	*98.3*	*8.0*	*1.38*
1	0.500 mm	*25.1*	*101.7*	*96.8*	*4.8*	*1.21*
0.500 mm	0.250 mm	*26.1*	*100.3*	*96.1*	*4.2*	*1.09*
0.250 mm	–	*16.2*	–	–	*4.2 (3)*	*0.68*
Total		*100*			Total	*6.08*
					Mean	6

Notes: (1) Less than 5% by mass of total sample, no test specimen.
(2) Taken as equivalent to that for 6.3 mm to 2 mm size under sub-Clause A.7.2, indent (b).
(3) No test but mass loss taken as equivalent to that for 0.500 mm to 0.250 mm size under sub-Clause A.7.3.

Appendix B – Test Method for Straightedge

B.1 SCOPE

This Appendix describes the method that shall be followed to determine the surface accuracy of pavement quality concrete in this Specification.

B.2 APPARATUS

B.2.1 The straightedge for the tests shall be purpose made and 3 m long. It shall have a flat square edge of metal, at least 25 mm wide, along the full length of its base. The straightedge may be fitted with lifting hand grips or handles.

B.2.2 A calibrated wedge must be used to determine the straightedge clearance. The wedge should have an angle of 5.75° ± 0.05°, and engraved at 10 mm intervals across the incline, starting at the apex, representing clearances increasing in 1 mm intervals up the incline.

B.3 PROCEDURE

B.3.1 The straightedge shall be placed unsupported on the surface, anywhere in any direction, other than across the crown of a camber or across a drainage channel. The location shall be selected by the Project Manager or his representative, and the tests shall be carried out in his presence.

B.3.2 Twenty tests shall be made for every 1000 square metres laid and at least half of these tests shall be across lane joints

B.3.3 The Contractor shall mark with distinctive markings all areas which fail to comply with the specified requirement .

B.3.4 Alternatively the areas may be identified by electronic means for future reference.

Appendix C – Tests for Manufactured Joint Fillers

C.1 SCOPE

The various tests described in this Appendix cover procedures to be followed to determine the resistance of manufactured joint fillers to freezing and thawing cycles and their ability to recover without shape loss after compression.

C.2 SAMPLES

The tests shall be carried out on 115 mm x 115 mm specimens cut from representative samples. The specimens shall be prepared to an accuracy of ± 2.5 mm with cleanly cut edges. When more than one thickness of filler is required in the joints, the test shall be carried out on specimens of each thickness. The thickness of the specimens shall be accurately measured.

C.3 WEATHERING TEST

C.3.1 At least 4 specimens of each thickness shall be dried in a ventilated oven at a temperature of 55°C ± 5°C for 7 days, after which they shall immediately be immersed in water at room temperature of between 16°C and 21°C for 24 hours. They shall then be subjected to 5 cycles of freezing and thawing in the following manner.

C.3.2 The specimens shall be placed in a watertight weathering test pan having a ribbed bottom and a fitted slotted lid designed to hold test specimens vertically on edge while allowing free flow of water around all the faces of each specimen. The pan shall be filled with water to half the depth of the specimens and then frozen to -7°C or below and retained at this temperature for at least 4 hours after the initial freezing of the water. The pan shall then be placed in a water bath maintained at 18°C to 38°C without disturbing the specimens and shall remain there for one hour after thawing has completed. The pan and specimens shall then be returned to the refrigerator and freezing and thawing shall be repeated in precisely the same manner until 5 cycles of the process have been completed. The specimens shall be removed from the pan and air dried at room temperature for 48 hours before examination.

C.3.3 The material shall be deemed to have passed the Weathering Test if all specimens are free from signs of disintegration or shrinkage.

C.4 COMPRESSION AND RECOVERY TEST

C.4.1 Two of the specimens of each thickness which have passed the Weathering Test and two new specimens shall each be trimmed to 100 mm x 100 mm to an accuracy of ± 0.5 mm. Each of these shall be subjected to 3 applications of load at 24 hour intervals in a compression test machine complying with BS EN ISO 7500-1, with auxiliary plattens 100 mm square and a minimum of 13 mm thick. During each application of load, each specimen shall be compressed to 50% of its original thickness at a rate of strain of 1.3 mm/minute. The pressure to attain this compression shall not be less than 0.7 N/mm² nor more than 10 N/mm². The load shall be released immediately the required degree of compression is reached and after the third application a recovery period of 30 minutes shall be allowed after which the thickness of the specimen shall be measured.

C.4.2 This thickness, expressed as a percentage of the original thickness, is the Recovery Value of the specimen. The thicknesses shall be measured to an accuracy of 25 microns. The 2 new specimens shall be weighed before and after testing. The difference in mass shall be determined with an accuracy of 0.1% and shall be expressed as a percentage of the original mass of the specimen.

C.4.3 The material shall be deemed to have passed the Compression and Recovery Test if all 4 specimens have Recovery Values of at least 70% and neither of the two new specimens has suffered a reduction in mass in excess of 1%.

C.5 EXTRUSION TEST

C.5.1 Two other specimens of each thickness which have passed the Weathering Test shall be trimmed to 100 mm x 100 mm to an accuracy of ± 0.5 mm and subjected to the following extrusion test.

C.5.2 The extrusion mould shall be 100 mm x 100 mm (+ 0.5 mm, -0) internally, of sufficient depth to test the sample as received, open on one side only and fixed rigidly to a base plate. The mould shall be fitted with a closely fitting pressure plate, which shall fit without binding, and with an accurate horizontal measuring dial gauge or measuring device accurate to 25 microns. The specimen shall be mounted in the extrusion mould and loaded once as described in the compression and recovery test. The extrusion at the open side of the mould shall be measured with the gauge when the specimen is compressed to 50% of its original thickness and before release of the load.

C.5.3 The material shall be deemed to have passed the Extrusion Test if, on both samples, the extrusion of the free edge does not exceed 6 mm.

C.6 IMMERSION TEST FOR SELF-EXPANDING CORK FILLER BOARD

C.6.1 Two specimens each 115 mm x 115 mm ± 2.5 mm shall be prepared and the thickness of each specimen shall be determined to the nearest 25 microns before the specimens are immersed in boiling water for at least one hour. After removal from the boiling water the specimens shall be allowed to cool to room temperature and after 15 minutes at this temperature their thicknesses shall be re-measured to the nearest 25 microns.

C.6.2 The material shall be deemed to have passed the Immersion Test if both specimens have a thickness of not less than 140% of their thickness before immersion.

C.7 ACID TEST FOR RESIN-BONDED FILLER BOARDS

C.7.1 Two specimens each 115 mm x 115 mm ± 2.5 mm shall be immersed in hydrochloric acid of specific gravity 1.18 at room temperature. The acid shall then be brought to the boil and maintained thus for one hour when the specimens shall be removed and rinsed in water.

C.7.2 The material shall be deemed to have passed the Acid Test when after examination neither of the specimens shows any evidence of loss of resilience, friability or evidence of disintegration. Discolouration or minor swelling shall not be considered as failure.

Appendix Y – Guidance Notes on Quality Systems for Project Managers

Y.1 INTRODUCTION

These Guidance Notes are intended to assist Project Managers in assessing Suppliers' Quality Assurance (QA) systems for the supply of component and mixed materials as required by Clause 2.4. In particular, guidance is given on:

- how to appraise and evaluate different Quality Systems offered by Suppliers when tendering for jobs (Clauses Y.5 and Y.6); and
- how to monitor work undertaken (Clause Y.7).

Separate clauses are devoted to each aspect.

Y.2 GENERAL

Y.2.1 These Guidance Notes are not intended to replace the BS EN ISO 9000 series and associated documentation.

Y.2.2 The generic term "Client" or "Purchaser" in these Guidance Notes is to include the person or organisation that is acting for, or on behalf of, the Property Manager or the Project Sponsor in the role of either a Project Manager or a Works Services Manager.

Y.2.3 The generic term "Supplier" is used to cover any person or organisation that has, or is tendering for, a Contract with the Client to supply a product or service, and includes those traditionally referred to as the (main) Contractor.

Y.2.4 Products which are specified by means of a Harmonised European Standard under the Construction Products Directive are subject to CE marking. It is not permitted to require additional quality assurance or testing requirements over and above those required for Attestation of Conformity within the European Standard. The CE mark certificate should be taken as sufficient evidence of product conformity.

Y.3 QUALITY SYSTEMS

Y.3.1 It is now the accepted practice that all suppliers of goods and services should:

- install and maintain a Quality Management System; and
- become registered to a National Accreditation Council for Certification Bodies (NACCB) accredited third party certification scheme as a Supplier of assessed capability.

Y.3.2 It is general practice that, once a Quality Management Scheme has been set up within an organisation, application for registration to a second or third party certification scheme will be made.

Y.3.3 Second party assessment is carried out by the purchasing organisation; this is very expensive because the resource requirements for systematic and continuous auditing and the management of an assessment scheme are extremely high. Consequently, this form of registration is now in decline and organisations which previously carried out second party assessment, such as British Telecom, British Gas, what used to be the National Coal Board and the MoD, are beginning to insist that their suppliers obtain third party assessment and, hence, pay the costs of quality assurance.

Y.3.4 Certification of a Supplier's Quality Management System by a third party should provide the Purchaser with the confidence that the Supplier is:

- operating and maintaining a fully documented Quality Management System that addresses consistent requirements; and
- operating within the scope of registration.

This avoids the need for the Purchaser to undertake his own structured regime of second party assessments to ascertain the adequacy and focus of the Supplier's Quality Management Systems.

Y.3.5 However, this does not absolve the Project Manager of his responsibilities on behalf of the Client to ensure that the Quality System of the Supplier addresses all the requirements and needs.

This is because the Quality Standards are interpreted differently by individual organisations.

Y.3.6 In principal, the more independent the assessment and audit regime, the more confident the Purchaser can be as to the value of a Supplier's Quality Management System. Once registered under a certifying body's scheme, there is still a need to audit, by both the Supplier and the third party certification body, that procedures and standards are being maintained.

Y.3.7 Assessments and audits can be carried out by:

- the Supplier's management – Under his own audit and monitoring regime;
- the Client (Project Manager) – Second party assessment scheme; or
- an independent body – Third party assessment scheme.

Y.4 PROCESSES COVERED UNDER THE QUALITY SYSTEM

Y.4.1 For a Quality Management System to be effective, it must cover all the operations and processes that are relevant to the business conducted by the Supplier.

Y.4.2 Dependent upon the type of work being tendered for, but as a minimum for the purpose of this Standard, the following areas should normally be addressed:

- procurement, inspection and safe storage of constituent materials;
- training of plant operatives;
- setting up on-site batching and mixing plants and the mixing of concrete;
- off-site supply and mixing of concrete;
- transportation of concrete;
- laying and compaction of concrete;
- inspection and test regimes and records at appropriate stages;
- sub-contractor/supplier assessment and control;
- calibration of equipment; and
- statistical techniques to be used for trend analysis, statistical process control and inspection.

Y.4.3 Quality Management Systems should include provisions for planned and systematic audits, inspections and tests by participating organisations. The Project Manager has the responsibility to evaluate and audit the system being operated by the Supplier to ensure adequacy. This should include checking records to substantiate that the procedures are being followed and that the Supplier has evidence that the materials and works are conforming to the specified standard.

Y.4.4 A Quality Plan in accordance with Defence Standard 05-67 should be stipulated in the Contract as a deliverable, but may be included in the *Invitation to Tender* if required. The activities described within the Quality Plan shall be stated unambiguously and concisely so that their intent is clear and that, upon implementation, they can be conducted, assessed, audited, demonstrated, measured or verified.

Y.4.5 The Quality Plan must state or contain definitions as to the levels of quality assurance and control to be applied throughout the Contract, which should include:

- traceability of materials;
- frequency and stages of inspections and tests;
- process controls; and
- records (including the retention periods and reviews).

Y.4.6 As quality standards are not extensively defined in relation to the process control, it is the responsibility of the Project Manager to ensure that all processes and methods proposed in Quality Plans are clearly defined and understood with regard to how the Supplier will deal with these aspects of the operation, and that all anomalies, shortfalls, errors and omissions are documented and resolved.

Y.5 ASSESSMENT OF QUALITY MANAGEMENT SYSTEMS

Y.5.1 The assessment of Quality Management Systems is a logical and progressive multi-stage process that encompasses good management precepts.

Y.5.2 A list and records should be maintained of acceptable suppliers and only suppliers on this list should be chosen. Therefore, any solicited or unsolicited suppliers should, as the first stage in the selection process, be required to complete a supplier questionnaire and must, as a minimum, include the following elements:

- verification/proof that the Supplier's Quality Management System is registered by a Certification Body accredited by NACCB;
- that the registration certificate is current;
- that the offices/sites from which the works or services are to be provided are covered by the registration certificate;

- that the scope of registration is appropriate for the works/services to be provided;
- experience or references of other users of the Supplier's services;
- the Supplier's past performance, covering experience and results with similar work/projects;
- financial information;
- insurance information; and
- Health and Safety information.

Y.5.3 If the responses to the above are satisfactory, an assessment of the Supplier's Quality System can be undertaken.

Y.5.4 The extent of the assessment can range from a visit to the Supplier's premises to overview the Quality Management System in operation on a similar project, to a full formal audit conducted against the BS EN ISO 9000 series and in accordance with BS EN ISO 19011 by the Project Manager's own QA staff.

Y.5.5 It is the responsibility of the Project Manager to decide if an assessment is necessary. The decision for, and the scope of, such an assessment should be taken on the basis of the size, complexity, cost and length/duration of the Contract in conjunction with the level of confidence that can be established from other sources.

Y.6 ASPECTS TO ASSESS TENDER ACCEPTABILITY

Y.6.1 The requirements for the purchasing of goods and services should, as a minimum, be those set down in the BS EN ISO 9000 series. In order to ensure successful procurement, it is a prerequisite that the purchaser (the Project Manager) provides a clear definition of requirements in the form of contractual conditions and specifications. This aspect applies equally to Quality Management System requirements.

Y.6.2 All *Invitations to Tender* must contain elements outlining the quality requirements. These should be in the form of asking tenderers to provide:

- proof of registration to the pertinent part of the BS EN ISO 9000 series with an appropriate scope of registration for that particular Contract;
- method statements for all processes to be carried out;
- inspection/test schedules; and
- other information relevant to the Contract.

Y.6.3 When the Supplier returns a tender, his submission must be scrutinised to assess whether his Quality Management System covers all the areas that are relevant to the processes necessary for him to carry out in order that the work is to the required standard. Where only part of the required elements are covered in the Quality Management System, it may be acceptable for the tenderer to address these areas in his Quality Plan and to compile site-specific procedures for unique elements of the Contract.

Y.6.4 The returned tenders must provide precise details against the information requested in the *Invitation to Tender*, which is to include the following:

- the Quality System that will be enforced throughout the duration of the Contract;
- the method and procedures to be used to ensure the positive identification and issue status of specifications, drawings, inspection instructions and other data including the requirements for the approval of operational procedures, equipment, staff, operative training and outputs;
- the method and procedures to be used to ensure the conformance to the Specification by processes, inspection and test criteria; and
- methods for the procurement of raw materials, services, etc.

Y.6.5 It is the responsibility of the Project Manager to select those suppliers that they consider will provide the level of confidence that they require to meet the Specification and fulfil their obligations under the Contract.

Y.6.6 Information, in the form of Inspection Records, Test Certificates and Certificates of Conformity, from the Supplier will not normally be supplied automatically unless particularly requested or a contractual requirement. To make sure that the Supplier understands these requirements, a Quality Plan can be required as part of the tender response. The Quality Plan must be evaluated as part of the tender selection process.

Y.6.7 Where the Supplier proposes that some of the work is carried out by sub-contractors, it does not absolve the Supplier of any of his responsibilities to ensure that the work is carried out to the contracted specification and quality.

Y.6.8 The Supplier is to ensure that, where sub-contractors have their own Quality Management System, it is found by scrutiny to be acceptable and they work to it. Where a sub-contractor does not have his own Quality Management System, the Supplier is to impose his own on the sub-contractor.

The Project Manager has a responsibility to audit both the Supplier and any sub-contractors to ensure compliance to the tender proposal.

Y.7 MONITORING THE QUALITY MANAGEMENT SYSTEM AND PROCESSES

Y.7.1 Whilst the Supplier may have registration to the BS EN ISO 9000 series, it does not necessarily mean that his system is fully focused on the specific requirements of the Contract, nor does any second party scheme run by another purchaser. Monitoring of the system should take place irrespective of whether the Supplier has, or has not, achieved registration.

Y.7.2 The Supplier should have procedures in place for the auditing, monitoring, recording and rectifying of all his activities. The Project Manager should ensure, by conducting surveillance audits of the Supplier's system, that:

- these are being carried out;
- the system is effective; and
- the system is focused on the Contract requirements and deliverables.

Y.7.3 Within the Contract, there are requirements for the Supplier to carry out tests on the materials, etc. The Supplier may not have his own test laboratory, in which case he will send samples out to a test house. Any test laboratory, whether part of the Supplier's organisation or an independent test house, conducting the tests for initial approval of materials and design of mixtures should be a United Kingdom Accredited Scheme (UKAS) accredited test house with an appropriate test schedule. Site laboratories used to carry out routine tests on bulk supplies and mixtures throughout plant mixing shall be either UKAS accredited or, subject to the Project Manager's approval, work to a Quality Assurance scheme.

Y.7.4 Where non-compliances are found, whether within the system being operated or the goods or services provided, they can be either random instances when the value is outside the specified range or an indication of a trend. If the running mean of the last, say, twenty results has remained reasonably consistent with a standard deviation that also has not fluctuated, then it is likely to be a random instance. Preferably, the running means and standard deviations should be monitored to allow corrective action before non-compliances occur. All actions taken to deal with non-compliances are to be documented.

Y.7.5 Rates of sampling and testing must be appropriate to the Contract and stated clearly in the Quality Plan. Where rates are stipulated in the Contract (see Section 8), these will take preference.

Y.7.6 The procedures for sampling and testing concrete and its constituent materials are to be in accordance with the appropriate parts of the latest editions of relevant British Standards, and also with the latest edition of the appropriate Appendices to this Standard. All samples and testing should be carried out by suitably trained personnel. The results are to be supported by valid Test or Sample Certificates.

Y.7.7 The use of a Quality System should minimise the need for the Project Manager to carry out his own tests. Therefore, they can:

- do nothing because the Supplier is carrying out sufficient inspections and tests, and assessing the results and implications;
- assess the Inspection and Test Results for the material provided for the Contract to ensure that checks are being made and that the results indicate compliance to the Contract and Quality Plan is being achieved; or
- conduct a separate inspection and test regime of his own to check for compliance.

Y.8 RECORDS

Y.8.1 The training records of all operatives, sampling and testing personnel are to be maintained by the Supplier and are to be made available for inspection.

Y.8.2 The results of all inspections, tests, etc. for the Contract should be obtained and retained for record purposes. All documentation (including work-sheets, Inspection and Test Certificates and Certificates of Conformity) that are relevant to the Contract should be:

- available at the place of work (usually the plant or depot) for inspection by the Project Manager for the duration of the Contract; and
- handed over to the Project Manager on completion of the Contract.

Appendix Z – Guidance Notes on the Preparation of Job Specifications

Z.1 COARSE AGGREGATE

Z.1.1 The Specification requires that the coarse aggregate for use in Pavement Quality Concrete be crushed limestone (see Clause 3.1.1). The main reasons for this are:

- Concrete made with limestone aggregate has a lower coefficient of thermal expansion than concrete made with other suitable natural aggregates. This allows the joints in a concrete pavement to be spaced at wider intervals, which is desirable because the joints are the most expensive part of a pavement to form and to maintain.
- Concrete made with limestone coarse aggregate is more readily sawn at an early stage of its hardening than concrete made with other suitable natural aggregates. This enables contraction joints in the pavement slab to be formed by sawing them, the most suitable method for good durability and riding quality.
- Gravels may contain a proportion of unsuitable particles, randomly distributed throughout their bulk, which is too small to be detected in approval tests but is large enough to cause unacceptable blemishment of the pavement. At a crushed rock source, unsuitable material can usually be detected during inspection of the quarry faces and avoided.

Z.1.2 Use of coarse aggregates other than crushed limestone is not recommended for Pavement Quality Concrete; however, where limestone is unavailable or is prohibitively expensive, use of another type of crushed rock, or even gravel, may have to be permitted. In those circumstances, other changes to the Specification clauses would be needed, as discussed below:

- The relationships between flexural strength (as used in the standard design procedure for MOD airfield pavements in A Guide to Airfield Pavement Design and Evaluation – Defence Estates 3rd Edition February 2011 and compressive strength (as adopted in this Specification for judging compliance) are different according to whether the coarse aggregate is crushed rock or gravel. The strength value requirements of the Specification may not, therefore, be applicable to concrete made with gravel aggregate.
- The layout of joints referred to in Clause 5.7 would need to be based on the maximum joint spacings given in Table 10 of A Guide to Airfield Pavement Design and Evaluation – Defence Estates 3rd Edition February 2011 and which is replicated at Table Z1
- It should still be possible to saw contraction grooves, as specified in Clause 5.26 and illustrated in Figure 5.2, in concrete made with other crushed rock coarse aggregates and some gravels, albeit at possible extra cost (sawing rates may be lower so that additional saws may need to be employed; saw blade wear may be increased). If the coarse aggregate is flint gravel, sawing at the early stage necessary when forming contraction joints becomes impracticable and the contraction joints have to be formed in the wet concrete during laying. Specification details and illustrations of wet-formed contraction joints are to be found in Defence Works Functional Standard 06 - Guide to Airfield Pavement Maintenance.

TABLE Z.1 MAXIMUM JOINT SPACINGS FOR UNREINFORCED PQ CONCRETE

Type of Joint	Type of Coarse Aggregate	Design Thickness of Slab (mm)				
		150	200	225	250	≥275
Expansion	Limestone	36m	48m	54m	None	None
	Other rocks and gravels	18 m	22.5 m	31.5 m	None	None
Contraction or construction	Limestone	4 m	4 m	6.75 m	6.75 m	7.5 m
	Other rocks and gravels	3 m	3 m	4.5 m	5.25 m	6 m

Z.1.3 Load transfer at transverse joints within heavily trafficked slabs should be considered and if necessary 40 mm aggregate used as per Clause 3.2.

Z.2 CEMENTS/ADDITIONS/STRENGTH

Cements to BS EN 197-1:2011 may be (CEMI, CEMII/A-S, CEMII/B-S, CEMII/A-V & CEMIIB-V) or Combinations to BS8500 may be of CEMI to BS EN 197-1:2011 with BS EN 15167-1:2006 or BS EN 450-1:2012 (CIIA-S, CIIB-S, CIIA-V & CIIB-V)

For specific airfield pavement projects DIO has on application permitted the use of conditioned siliceous fly ash. This has been in conjunction with well controlled onsite batching. It is well known that fly ash has been used on major civil airport pavements mainly up to flexural strength F6. The benefits are well established and ensure reduction in carbon footprint as well as contributing to continued strength gain compared to the use of CEM I.

Therefore when using cement additions the relationships between compressive strengths from cores, cubes and beam flexural beam tests are to be established in the laboratory and by way of the trials

At Table Z2 DIO now also provides “indicator” mean corrected core strength values for cores cut from the pavement tested at 28 days for F5, F5.5, and F6 flexural strength concrete. These values are respectively 48, 53 and 57 N/mm^2. It is envisaged that these values for flexural concrete may be used at early tender stage, but always then subject to a verification /amendment deriving from laboratory and site trials before inclusion in the permanent works This verification is required to establish the relationships between compressive strengths from cores, cubes and 500 mm flexural beam tests. Therefore the Contractor will be required to update/insert values in the Table Z2 rows with the relevant information resulting from the trials. This to ensure that the design flexural strengths are met.

(NOTE: The “indicator” figures above have been chosen using a combination of feedback from industry and by reference to relationships between flexural and compressive strengths at 28 days contained within TRL Report 630 with the values referenced to the 28 day compressive strength of 43 N/mm^2 for F4.5 flexural strength concrete)

Z.3 AIR ENTRAINMENT

Z.3.1 The prime purpose of entraining air in Pavement Quality Concrete is to improve the resistance of the pavement slab to damage by frost or anti- or de-icing chemicals. However, the presence of the entrained air also alters other properties of the concrete, most importantly its consistence and its hardened strength.

Z.3.2 The quantity of air entraining admixture to be included in the Pavement Quality Concrete mix to provide the entrained air content specified in Clause 4.3 of the Specification will be established during the trial mix and trial area procedures specified in Clauses 6.1 and 6.2. At that same time the other proportions of the mix will be determined so that the specified strength and consistence requirements are satisfied when the mix contains the correct entrained air content. During the course of the work, temperature change may influence the effectiveness of the air entraining admixture and the dosage determined during the trials may no longer produce an air content within the specified range. The air content determinations specified in Clause 5.15.3 require careful monitoring and immediate response by adjustment to the dosage of air entraining admixture; otherwise, variations in consistence consequent on air content change will make cross-bay slumping difficult to control (and hence surface regularity requirements more difficult to achieve) and, furthermore, strength values may fall (according to rule of thumb, a 1% increase in entrained air content will produce a 5% decrease in the strength of the hardened concrete).

Z.3.3 Variations in the "flour" content in the limestone aggregate may also be responsible for alterations in the content of entrained air that is produced by a given quantity of air entraining admixture. Such variations will in themselves bring about changes in consistence and other properties of the fresh concrete and if of sufficient magnitude will require more drastic action, such as washing the coarse aggregate to reduce the fines content to a lower and more consistent level.

Z.3.4 As indicated in Clause 3.7 the compatibility of combining air entrainment and with water reducing admixtures is to be obtained. One concern is that if ambient conditions were to change during production so that the air content entrained by the initially agreed dosage of the admixture no longer fell within the specified range, then change of dosage would result in a change of consistence, making cross bay slumping more difficult to control. Other concerns are given in Z.4.1

Z.4 ADMIXTURES

Z.4.1 In the past, the use of all admixtures other than air entraining admixture has been prohibited in standard specifications for airfield pavement works on UK military airfields. The reasons for this included:

- Uncertainty as to the effect products might have on the "finishability" of the concrete and hence on the surface durability.
- Some products influence the effectiveness of air entraining admixtures.
- Small changes in dosage of plasticisers produce large effects on consistence; since uniform consistence is essential if surface regularity requirements are to be maintained despite cross bay slumping, plasticisers were not considered desirable.
- Above all, since satisfactory pavements could be produced without using admixtures, there seemed little point in inviting potential difficulties by introducing them.

Z.4.2 This Specification permits the use of slip-form pavers and, to allow Contractors the maximum flexibility in designing concrete mixes to suit this equipment, admixtures have also been introduced in one of the alternatives for Clause 3.7.1.

Z.4.3 If Project /Works Services Managers decide that use of a slip-form paver would be a suitable construction method on a particular project and therefore include Clause 5.18 in their specification, then it is suggested that the alternative wording allowing admixtures be selected for Clause 3.7.1. If, however, it is decided that use of a slip-form paver would not be appropriate on a particular project, unless the Project Manager is confident that the use of certain admixtures would not be detrimental to the finished work, it is suggested that the alternative wording prohibiting admixtures be selected for Clause 3.7.1.

Z.5 JOINT SEALING COMPOUNDS

Z.5.1 Clauses 3.12, 5.28 and 5.29 allow for either hot or cold applied joint sealing compounds to be used. It will normally be acceptable to leave both alternatives in an individual job specification, leaving it to the Contractor to choose which to use on the basis of price and circumstances.
(NOTE: For any joint sealant due regard is to be given to the expected movements and the aspect ratio i.e. width & depth of the sealant as this is relevant to an effective & enduring engineered design)

Z.5.2 To cover the cases where cold applied compounds are selected, the drawings should indicate which areas, if any, require fuel and flame resistant grade compound (i.e. Type FB in accordance with BS 5212: Part 1). Use of this grade will usually be limited to areas where jet engine exhaust efflux at high velocity is likely to impinge upon the pavement surface. Runway ends and installed engine test areas may therefore require this grade of compound, depending on the configuration of user aircraft.

Z.5.3 For material initially tested and manufactured to ISO9001 batch certificates are required from the manufacturer to indicate that the sealant is fit for purpose.
[NOTE: Previous, oft perceived, onerous DIO test requirements have indicated that job specific testing is unachievable in practice due to high costs, unrealistic expectations on quantities and the timescales involved].

Z.6 CONCRETE STRENGTH

Z.6.1 In Clause 4.6.1 of the Specification, three alternative values, [43] (38) and {34} N/mm², are given for the required mean corrected core strength of cores cut from the pavement and tested at (28 ± 3) days. The values specified first, in square brackets, here and subsequently in Clauses 4.6.2, 5.15.2, 5.27.1, 6.1 and 6.2 of the Specification, are intended to satisfy the requirement for a mean in-situ flexural strength of 4.5 N/mm² at 28 days adopted for the examples illustrating use of the design charts for rigid pavements in A Guide to Airfield Pavement Design and Evaluation – Defence Estates 3rd Edition February 2011.

Z.6.2 The set of strength values given in the square brackets are relatively high for pavement concretes and their achievement may present some difficulties. For example, the high cement content necessary to achieve these values impacts on the reactive alkali content , often with consequence on the choice of fine aggregate. It for this reason that the previous limit of 3.0kg/m3 is now increased to 3.25 kg/m3 specified in Clause 4.5 as a precaution against alkali-silica reaction.

Z.6.3 Designers and specifiers may prefer to adopt a lower design value 28 day mean in situ flexural strength, increasing slab thicknesses accordingly. The second and third alternative sets of values will satisfy requirements for mean, in-situ, flexural strengths at 28 days of 4.0 and 3.5 N/mm², respectively. (The choice of the first, second or third alternative in Clause 4.6.1 must, of course, be followed by selection of the corresponding set of values through all subsequent clauses).
(NOTE: As mitigation against ASR additional measures may be taken e.g. regular inspection/testing of the fine aggregate sources to verify that the reactive alkali contributed by chloride contamination of aggregate is lower than might otherwise be the case.- see Sect 4.5.3)

Z.7 CONCRETE MIXERS

Z.7.1 The Specification requires the concrete batching plant(s) and mixer(s) to be set up within the site boundary (see Clause 5.5.2). Although this may be more expensive than using an off-site readymix plant and in some cases may require contract periods to be longer to allow for the erection of the plant, the following advantages make on-site batching and mixing the preferred technical and value for money arrangement:

- The type and size of mixer and batching system can be selected and the set up of the bins, silos, etc., can be tailored to suit the requirements of the project.
- The Project Manager and the Contractor can check materials, batching and mixing easily, quickly, frequently and economically.
- Only those cements, aggregates and additives approved for the project are on site so other materials cannot be used erroneously.
- The quality control regime can be organised with emphasis on the particular requirements of this Pavement Quality Concrete Specification.
- Transport delays for mixed concrete are avoided, allowing a smooth continuity of laying.
- Transport time for mixed concrete is minimised, making it more likely that the 90 minutes allowed between adding water to the mix and applying the curing membrane to the finished concrete (see Clause 5.24) will be complied with and that entrained air contents will be consistent.
- Quick reaction to events is possible (e.g. heavy rain starting; air content drifting out of specified range and needing correction; breakdown of items of spreading, compacting or finishing equipment), reducing wastage and avoiding pressure to lay loads already in transit under unsuitable conditions.
- There is no competition with other customers for mixer time or delivery vehicles.
- Drivers of delivery vehicles are on the contract works full time and so can be properly briefed for driving on active pavements and, if necessary, vetted for security purposes.

- A single organisation is responsible for both the production and laying of concrete and therefore better cooperation is likely when adjustments to the mix are necessary to facilitate laying or finishing.
- The choice of appropriate readymix plants within a suitable road distance of the site may be limited or even non existent, particularly for more remote airfields.

Z.7.2 Interruptions to the continuity of concrete laying are detrimental to the quality of the finished pavement no matter which method of laying is being used and are particularly so for a slip-form paver. When tenderers submit their proposals for concrete mixers, particular attention should therefore be paid to ensuring that the rate of output will be sufficient.

Z.7.3 Close attention also needs to be paid to the methods for introducing and distributing the air entraining admixture (the effects of varying air content are discussed at Z.3 above). To ensure even distribution of the entrained air, mixing times may have to be longer than normally recommended for the mixer; once agreed, however, the mixing time should be kept constant since mixing for too long may cause over-entrainment with some admixtures, or gradually expel air.

Z.7.4 A prerequisite for good Pavement Quality Concrete is consistency of production at the mixing plant. This is particularly so when the concrete is to be laid by means of a slip-form paver. Mixers incorporating devices which constantly monitor and adjust for variability in the fine aggregate moisture content and which allow precise control of consistence by permitting a final dribble-feed of water into each batch under consistometer gauge check will, when used by experienced operators, greatly aid the production of consistent concrete.

Z.8 SPREADING, COMPACTING AND FINISHING CONCRETE

Z.8.1 Clause 5.18 relates to slip form paving.

Z.8.2 Clause 5.17 is concerned with the use of semi-mechanised construction methods.

Advantages of specifying semi-mechanised construction include:

- The method is likely to be the most economical one where the size and shape of the area dictate that construction will be mainly in runs of less than, say, 200 m.
- The items of plant involved and crews skilled in their use are likely to be readily available.
- Production rates are relatively low and consequently construction periods are likely to be longer than for the alternative methods.
- Surface regularity standards, particularly in the longitudinal direction, which is the most important for aircraft ride quality, are likely to be inferior to those obtainable using a skilfully operated paving train.
- More hand finishing is involved, which may bring laitance to the surface and reduce durability.
- The number of "day joints" (i.e. transverse construction joints), which have no load transfer arrangement and therefore are weak spots in the pavement likely to require early maintenance attention, will usually be greater than in pavements laid by the alternative methods.

Z.8.3 Clause 5.18 is concerned with the use of slip-form pavers. This type of equipment has been used often in other countries for constructing airfield pavements and in UK for highway work and is becoming more widespread for UK airfield works. Rates of output and economy of production on suitably large areas are potentially considerably better than for either of the alternative methods. Slip-form paving operations involve a continual struggle to counter the tendency of the edges of the unsupported slab behind the paver to slump. Acceptable standards in respect of surface regularity can be achieved and maintained throughout but mix design, control of production of concrete and control in the laying process are likely to be more critical than when laying between forms. These considerations will be particularly important for work on runways and certain taxiways, where directional control and ride quality for aircraft are most critical.

For slip-forming to be successful, an essential provision is a dedicated concrete batching and mixing plant with an output large enough to ensure a constant supply of concrete to the paver and which allows tight control so as to ensure that the concrete has consistent properties from batch to batch. Tenderers' proposals in this respect, submitted in accordance with Clause 5.5, should be checked carefully.

Advantages of specifying slip-form pavers include:

- Rates of output are potentially superior to those obtainable by other methods, so construction periods should be shorter.

- Potentially the most economical method for a large area.
- Quality of concrete mix is consistently good (otherwise the method will not work at all).
- Number of "day joints" is low.

Disadvantages include:
- Surface regularity standard maybe inferior to that obtainable by other construction methods, particularly across lane joints.
- The presence of AGL fittings, pits, manholes, etc., in the pavement may interfere with the slip-forming operation, requiring some of these to be repositioned.

Z.8.4 The aim of the concrete placing operations specified in Clauses 5.17 and 5.18 is to produce a durable finished concrete surface, textured where required, that is free of surface defects and blemishes. A properly trialled and well designed concrete mix combined with well controlled placing, compacting and finishing techniques should be able to produce a surface virtually free of defects. In reality, a totally blemish free surface is difficult to achieve and a small degree of surface defects may be acceptable. Overworking of the concrete surface by hand floating and/or application of additional water in order to create a weak sand/cement mortar (laitance) to smooth out defects should not be permitted.

Small, shallow, isolated dragging cracks are not generally a problem and some larger cracks may be acceptable on shoulders. Dragging cracks are usually a symptom of problems with the mix design and/or laying process. Depth of cracking may be assessed using cores.

Crazing is generally associated with poor curing and/or excessive laitance and acceptability is dependent upon extent and severity. A large crack pattern with shallow cracks in sound concrete is unlikely to be a problem. A small pattern with deep cracks in a thick mortar layer is not acceptable and affected bays should be removed. The severity of the cracking may be assessed using cores.

Z.9 LAYOUT OF JOINTS

Section 5.7 refers to the layout of joints and the provision of drawings. The positions of all openings through the PQC slab over manholes or pits and for lighting blocks or fittings shall be as shown on the Contract drawings.

The layout of the joints detailed below shall be designed so that the sides of these openings are at least 1 m from any slab edge, joint or groove. Alternatively, the line of slab edge, joint or groove shall coincide with the sides of the openings or shall be broken across the openings.

Expansion joints as Clause 5.19 are to be formed between new and existing PQC pavements, at junctions and around box gutters. They shall also be provided around other obstructions in the continuity of the slab.

After determining slab edge, joint or groove lines in relation to openings, obstructions, changes of direction and junctions, the areas of PQC surfacing between such lines shall be divided into square bays by longitudinal joints, which are continuous along the length of the pavement, and transverse joints, which are continuous across the width of the pavement. The spacing of these joints and grooves shall not exceed the values given in Table Z1

In general, the square bays shall be defined by construction joints as Clause 5.20 and contraction grooves as Clause 5.26. In some instances expansion joints as Clause 5.19 may take the place of construction joints or contraction grooves. The spacing of expansion joints shall not exceed the values given in Table Z1

Where irregularly shaped bays are unavoidable they shall not be less than half the area of the square bays and the layout shall be arranged to avoid internal angles sharper than 60°. No bay shall have a ratio of length: breadth greater than 1.5 : 1.

Z.10 CONSTRUCTION AND CONTRACTION JOINTS

Z.10.1 During the preparation of the Contract Documents, Project Managers must decide whether, and in which areas, construction joints and contraction grooves may be left unsealed, because it is stated in Clause 5.29 of the Specification that such information will be shown on the drawings.

Z.10.2 For more than 20 years, the usual practice on UK military airfields has been to leave construction joints and sawn contraction grooves in concrete pavements unsealed. This is obviously cheaper than sealing the joints and also removes the costs and disruption of periodic resealing. A past survey of the performance of sealed and unsealed joints showed that sealed joints sustain at least as much spall damage as unsealed. For most pavements, therefore, there appears to be no need to change previous practice and construction and contraction joints should continue to be left unsealed.

Z.10.3 There are, however, circumstances under which the sealing of construction and contraction joints is necessary. Among these are:

- In areas where fuel, lubricating oils, hydraulic fuels or other potential pollutants are regularly spilled (e.g. aircraft servicing platforms, runway ends and taxiway holding areas), joints should be sealed to minimise the likelihood of pollution when the airfield overlies or is in proximity to an aquifer.
- Where fine aggregate may be blown or become washed onto the pavements and into the joints. This would prejudice the ability of joints to accommodate thermal movement and could lead to compression failure of the pavement.
- Where the client prefers all joints to be sealed (e.g., on work for US Forces).

Z.10.4 Figure 5.2 of the Specification gives alternative details for sealed and unsealed joints. Clause 5.29 details how joints should be prepared for sealing and then sealed.

Z.11 FINAL CURING

Z.11.1 When Pavement Quality Concrete is being laid near to existing pavements which are to remain in use during the construction work, there is some risk that the polythene sheet referred to in Clause 5.25.3 might be blown loose by wind and become hazardous to aircraft. An alternative to polythene which might be considered for these circumstances is a second sprayed application of the curing compound, although this has the disadvantage of forming a thick membrane which may be rather slow to break down and so may interfere with the application of airfield ground markings. A curing membrane is available which is sprayed on and which can be peeled off at the end of the curing period.

Z.11.2 Wax based curing compounds are also available to ASTM Specifications. However due regard is to be given to the possibility of aircraft skidding on remnant wax. Wax residues are to be removed prior to lining works. Any proposal to use wax based compounds should be risk assessed and referred back to the DIO Airfield Pavement Team.

Z.12 SEPARATION MEMBRANE

A polythene membrane is required wherever the underlying surface is of a rugous nature. Therefore it is required for handlay situations, however well laid slipformed pavements immediately laid on an untrafficked and well presented underlying drylean concrete layer may omit the membrane layer, subject to Project Manager approval and designer confirmation that reduction of friction at slab base will be achieved by curing compounds or spray treatment and that the omission will not promote cracking in the slab. Also that there will be no loss of fines & moisture from the slab during curing due to the omission.

[NOTE: Further information is provided within the Britpave publication at pages 21 and 22 Concrete Hardstanding – Guidelines for the Design of Concrete Hardstandings 2nd Edition 2007]

Z.13 PRECAUTIONS AGAINST ASR

The DIO specified limit of total mass of reactive alkali in PQC is 3.25 kg/m3. Its calculation is based on the summation of the contribution from cement (including additions), aggregates (both coarse and fine) and other sources – see clause 4.5.5.

It should be noted that this calculation includes the reactive alkali contributed by the chloride ion contribution – see clause 4.5.3.

Background

Amongst the amendments introduced to BS8500 in 2012 and continued in the 2015 update were requirements for demonstrating that the risk of damaging alkali-silica reaction (ASR) has been minimized.

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The following text gives extracts and guidance derived from BS8500:2015

Annex B of BS8500-2:2015

The risk of ASR is minimized by adopting one of the sets of rules given in the Annex B. The 2015 British Standard replaced earlier references to BRE Digest 330 which contains the historical basis for the rules.

However the guidance in BRE Digest 330 is still a useful source of information and BRE Digest 330 Part 1:2004 includes the background to the chloride ion contribution to reactive alkali.

Definitions in BS8500*:*

Certified average alkali content (CAA)- Average of 25 consecutive determinations of alkali content carried out on spot samples and expressed as the Na_2O equivalent

Declared mean alkali content (DMA)-Alkali content of cement or addition, expressed as the Na_2O eq. as declared by the manufacturer. This is based on the certified average alkali content and includes a margin which takes into account the variability of production so that the certified average alkali content plus the margin shall not exceed the declared mean alkali content, without prior notice.

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Guaranteed alkali limit (GAL)- Alkali limit, expressed as the Na_2O eq. which the supplier guarantees is not exceeded by any test result on any spot sample

Alkali Content of Concrete

This is calculated from the mix proportions and the determined alkali contents of each of the constituents, for cementitious materials this is the DMA. BS8500 recognises that alkali contents of individual cement/addition samples can be higher or lower than the declared mean value due to, for example, manufacturing and test variations. The limiting criteria take this into account.

GGBS and Fly Ash

Using these materials reduces the risk of ASR and BS8500 permits the following relaxations

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Material	Replacement %	%Na_2O taken into account
GGBS	=> 40	0
	25-39	50
	< 25	100
Fly ash	=> 25	0
	20-24	20
	< 20	100

Aggregate Reactivity

Four classifications of reactivity are listed in BS8500:

1. Low
2. Normal
3. High
4. Extreme

Most aggregates fall into the first two classifications.

The DIO requirement is limestone which typically falls into the low reactivity classification.

BS8500 Alkali Limits for Concrete Aggregate Reactivity

The following not to be exceeded limits are given in BS8500 when the coarse and fine aggregates are classified in accordance with Annex B4 of BS8500

Low reactivity aggregate 5.0kg/m3

Normal reactivity aggregate 3.5 kg/m3

DIO as Specifier

The DIO requirement is that a maximum 3.25 kg/m^3) (Clause 4.5) be allowed and that full calculations be provided. This requires obtaining for the various sources accurate regular information .Of concern is the possible variability in the fine aggregate sources. DIO experience is that ASR on some airfields may be attributed to deficiencies within the fine aggregate source. Additional job specific inspections at the quarry and more regular testing of fine aggregate sources may be implemented to mitigate ASR (see note at Sect Z6.3)

General Notes

1. The BRE Digest 330 classification of cement into low, medium and high alkali no longer applies. For standardized prescribed concrete the risk of ASR is considered minimized by either:

a) conforming to the guidance given Annex B of BS8500 :2015

b) using a low alkali cement (GAL not more than 0.5%).

2. Whilst the recommendations in Annex B of BS8500 indicates that there is no evidence in the UK of damaging ASR in concrete made with normal reactivity aggregates at alkali contents

below 4.8 kg/m³ Na_2O equivalent the DIO view is that FOD mitigation on military airfields needs special attention. Therefore the 3.25 kg/m³ limit is applied. DIO Airfield Pavements Team may be consulted for further discussion guidance.

Z.14 EXAMPLE- CALCULATION FOR REACTIVE ALKALI

Refer to Specification Clause 4.5 for the reactive alkali limit of 3.25 kg/m³

Refer to Appendix Z13 for further information on reactive alkali and the relaxations permissible by use of additions such as fly ash

An Annual Declaration letter as DMA (Declared Mean Alkali Limit) is typically provided on a cement manufactures certificate

Example:

DMA is 0.75 and the proposal is to use 20% fly ash. Hence from the BS8500 table (replicated at Z13) the fly ash is in the band 20% to 24%. Therefore 20% of reactive alkali may be used in the calculation opposite :
In this example the calculations indicate that the alkali contribution of 2.949 kg/m³ is within limit

[Note: The 0.76 used for the fine and coarse aggregate calculation is referred to at Clause 4.5.3 and is referred to in BRE 330 Part 1]

	a	b	c	d
Material	kg/m³	Chloride values on Aggregate Properties data sheet	Alkali calc.	Alkali quantity kg/m³
Cement (CEM I) 80%	356	0.750	axb	2.670
Fly ash 20%	89	0.600	axbx0.2	0.106
Aggregate (4-20mm)	1100	0.001	axbx0.76	0.008
Sand	600	0.360	axbx0.76	0.164
Admixture	1.2			0.000
Water	160			0.000
TOTAL				**2.949**
			Limit - clause4.5	3.250

Table Z2 - Table of Concrete Compressive Stresses for Concrete Flexural Strengths F3.5 N/mm² to F6 N/mm²

Note : Refer to Clause 4.6.1 and the text in Appendix Z2

Definition	DIO 033 Clause	DIO Specification 033 "Indicator" Values for CEM I			DIO Specification 033 Values for CEM I		
		F 6	F 5.5	F 5	F 4.5	F 4	F 3.5
mean of the corrected core strength values at 28 days ± 3 days	4.6.1	57	53	48	43	38	34
mean of 7 day cube strength values	4.6.2	60	55	50	45	40	35
mean of 7 day cube strength values	5.15.2.3	60	55	50	45	40	35
min individual cube strength at 7 days	5.15.2.4	46	42	38	34	30	26
min mean 28 day corrected core strength (for four cores taken if cube strength is below above figures)	5.15.2.4	56	49	42	36	31	28
min individual 28 day corrected core strength (of four cores from above)	5.15.2.4	43	36	31	32	28	25
corrected core strength at (28 ± 3) days shall not be less than (for cores taken from hardened concrete)	5.27.1.5	*	*	*	32	28	25
mean 35 day corrected core strength	5.27.1.6	*	*	*	38	34	29

min individual 35 day corrected core strength	5.27.1.6	*	*	*	35	30	26
min mean 28 day corrected core strength value	5.27.1.7	*	*	*	43	38	34
28 day corrected core strength at work shall cease if mean value from a set of results is below	5.27.1.7(ii)	*	*	*	38	34	29
mean 28 day corrected core strength limit (to inform Project Manager of pavement area for removal)	5.27.1.7(ii)	*	*	*	43	38	34
mean of 7 day cube strength values from trial mix	6.1.2	60	55	50	45	40	35
mean of 7 day cube strength values from trial area	6.2.3	60	55	50	45	40	35
minimum individual cube strength value of one of the above cubes	6.2.3	46	42	38	34	30	26
mean corrected core strength value of trial area at (28 ± 3) days	6.2.6	57	53	48	43	38	34
minimum individual corrected core strength value from trial area	6.2.6	43	36	35	32	28	25

Note : The "indicator" figures for F5.0, F5.5 and F6 were included following consultation with industry through Britpave. The establishment of the values indicated by * in the table above will be provided by DIO as and when sufficient feedback is obtained from future DIO projects. In the interim these * values are to be determined on a project specific basis by the Project Manager in conjunction with the Contractor following the cube, core, beam testing referred to in Clause 1.7 v. (Projects using concrete F4.5 and below require cube, core, beam testing to be undertaken for DIO research purposes.-see Clause sect 1.7 vii)

References

Defence Infrastructure Organisation, Ministry of Defence

FS 06 1994 Functional Standard 06, Guide to Maintenance of Airfield Pavements

SPEC 12 2010 Specification 012, Hot Rolled Asphalt and Asphalt Concrete (Macadam) for Airfields

SPEC 13 2009 Specification 013, Marshall Asphalt for Airfields

SPEC 33 2005 Specification 033, Pavement Quality Concrete for Airfields

SPEC 35 2005 Specification 035, Concrete Block Paving for Airfields

SPEC 40 2009 Specification 040, Porous Friction Course for Airfields

SPEC 45 2009 Specification 045, Slurry Seal (Bitumen Emulsion) for Airfields

SPEC 49 2009 Specification 049, Stone Mastic Asphalt for Airfields

SPEC 50 2009 Specification 050, Recycled Bound Materials for Airfields

SPEC 51 2014 Specification 051, Cement Bound Granular Material for Airfields (DLC)

SPEC 52 2014 Specification 052, Hydraulically Bound Granular Material for Airfields

DMG 27 2011 Design and Maintenance Guide 27, A Guide to Airfield Pavement Design and Evaluation

DMG 33 2011 Design and Maintenance Guide 33, Reflection Cracking on Airfield Pavements – a design guide for assessment, treatment selection and future minimisation

Britpave Publications

(Refer to the Britpave website, Britpave.org.uk, for the extensive range of publications which include the following Guidance and Best Practice Notes)

Airfield Pavement Guidance Notes:

1. Concrete joints and joint sealing

4. Surface Finish, regularity and texture

Best Practice Notes:

BP01 Concreting Pavements in Winter

Design Handbook:

Concrete Hardstanding - Guidelines for the design of concrete hardstandings 2nd Edition 2007] (pages 21 and 22)

Building Research Eatablishment

BRE Digest 330 Part 1 2004 Alkali-silica Reaction in Concrete :Background to the guidance notes

British Standards Institution

BS 434 Bitumen road emulsions (anionic and cationic)

Part 1 2011 Specification for anionic bitumen road emulsions

Part 2 2006 Code of practice for use of cationic bitumen emulsions on roads and other paved areas

BS 1881 Part 103 1993 Compacting factor test

BS 3136 Specification for cold emulsion spraying machines for roads

Part 2 1972 Metric units

BS 3984 1982 Specification for sodium silicates

BS5212 Cold Applied Joint Sealant Systems for Concrete Pavements

Part 1: 1990 Specification for Joint Sealants

Part 2: 1990 Code of Practice for the Application and Use of Joint Sealants

Part 3: 1990 Methods of Test

BS 594987 2015 Asphalt for roads and other paved areas – Specification for transport, laying and compaction and design protocols

BS 7542 1992 Method for test for curing compounds for concrete

BS 8500			Concrete – Complementary British Standard to BS EN 206-1 -
	Part 1	2015	Method of specifying and guidance for the specifier
	Part 2	2015	Specification for constituent materials and concrete

CEN standards

BS EN 196			Methods of testing cement
.			
	Part 1	2016	Determination of strength
	Part 2	2013	Chemical analysis of cement
	Part 3	2005	Determination of setting time and soundness AMD: October 31, 2009
	Part 7	2007	Methods of taking and preparing samples of cement
	Part 21	1992	Determination of the chloride, carbon dioxide and alkali content of cement (see also Pt2)
BS EN 197			Cement.
	Part 1	2011	Composition, specifications and conformity criteria for common cements
	Part 2	2011	Conformity evaluation
BS EN 206			Concrete
		2013	Specification, performance, production and conformity
BS EN 450			Fly ash for concrete
	Part 1	2012	Definitions, specifications and conformity criteria
	Part 2	2005	Conformity Evaluation
BS EN 932			Tests for general properties of aggregates.
	Part 1	1997	Methods for sampling
	Part 2	1999	Methods for reducing laboratory samples
BS EN 933			Tests for geometrical properties of aggregates
	Part 1	2012	Determination of particle size distribution. Sieving method
	Part 2	1996	Determination of particle size – Test sieves, nominal size of apertures
	Part 3	2012	Determination of particle size – Flakiness
BS EN 934			Admixtures for concrete, mortar and grout.

	Part 1	2008	Common Requirements
	Part 2	2009	Concrete admixtures. Definitions, requirements, conformity, marking and labelling AMD Nov30:2012
	Part 5	2009	Determination of the water content by drying in a ventilated oven
	Part 6	2001	Sampling, conformity control and evaluation of conformity
BS EN 1008		2002	Mixing water for concrete. Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete
BS EN 1097			Test for mechanical and physical properties of aggregates
	Part 2	2010	Methods for the determination of resistance to fragmentation
	Part 3	1998	Methods for the determination of loose bulk density and voids
	Part 6	2013	Determination of particle density and water absorption
	Part 8	2009	Determination of the polished stone value
BS EN 1367			Test for thermal and freezing and thawing properties of aggregates
	Part 2	2010	Magnesium sulphate test
	Part 4	2009	Determination of drying shrinkage
BS EN 1744			Tests for chemical properties of aggregates
	Part 1	2009	Chemical analysis
BS EN 12620		2002	Aggregates for concrete
BS EN 13036			Road & Airfield Characteristics – Test methods
	Part 7	2008	Method of measuring surface irregularities: The straightedge test
BS EN 13043		2002	Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas
BS EN 13108			Bituminous mixtures – Material specification
	Part 1	2006	Asphalt concrete
	Part 4	2006	Hot rolled asphalt
	Part 7	2006	Porous asphalt
	Part 8	2006	Reclaimed asphalt
	Part 20	2006	Type testing of asphalt mixes
	Part 21	2006	Factory production control
BS EN 12350			Testing fresh concrete.

	Part 1	2009	Sampling
	Part 2	2009	Slump test
	Part 4	2009	Degree of compactability
	Part 7	2009	Air content. Pressure methods
BS EN 12390			Testing hardened concrete.
	Part 1	2012	Shape, dimensions and other requirements for specimens and moulds
	Part 2	2009	Making and curing specimens for strength tests
	Part 3	2009	Compressive strength of test specimens
	Part 5	2009	Flexural Strength of test specimens
	Part 7	2009	Density of hardened concrete
BS EN 12504			Testing concrete in structures.
	Part 1	2009	Cored specimens. Taking, examining and testing in compression
BS EN 12620		2002	Aggregates for concrete +A1:2008
BS EN 13036			Road and airfield surface characteristics. Test methods -
	Part 1	2010	Measurement of pavement surface macrotexture depth using a volumetric patch technique
	Part 7	2003	Irregularity measurement of pavement courses- The straightedge test
BS EN 13808		2013	Bitumen and bituminous binders – Framework for specifying cationic bitumen emulsions
BS EN 13863			Concrete pavements – Test methods.
	Part 3	2005	Determination of the thickness of a concrete pavement from cores
BS EN 13877			Concrete pavements
	Part 1	2013	Materials
	Part 2	2013	Functional requirements for concrete pavements
BS EN 14188			Joint fillers and sealants
	Part 1	2004	Specifications for hot applied sealants
	Part 2	2005	Specifications for cold applied sealants
	Part 3	2006	Specifications for preformed joint seals
	Part 4	2009	Specifications for primers to be used with joint sealants
BS EN 15167			Ground granulated blast furnace slag for use in concrete, mortar and grout

	Part 1	2006	Definitions, specifications and conformity criteria
	Part 2	2006	Conformity Evaluation
BS EN 30011			Guidelines for auditing quality work
	Part 1	1993	Auditing
	Part 2	1993	Qualification criteria for quality systems auditors
	Part 3	1993	Management of audit programmes
BS EN ISO 9000		2000	Quality management systems. Fundamentals and vocabulary
	Part 1	1994	Quality management and quality assurance standards. Guidelines for selection and use
BS ISO 9000			Quality management and quality assurance standards.
	Part 2	1997	Generic guidelines for the application of ISO 9001, ISO 9002 and ISO 9003
BS EN ISO 9001		2000	Quality management systems. Requirements
BS EN ISO 9000		2005	Quality management and quality assurance standards
BS EN ISO 19011		2002	Guidelines for quality and/or environmental management systems auditing
BS ISO 13473			Characterization of pavement texture by use of surface profiles.
	Part 2	2002	Terminology and basic requirements related to pavement texture profile analysis
	Part 3	2002	Specification and classification of profilometers
PD 6691		2015	Asphalt – Guidance on the use of BS EN 13108 “Bituminous Mixtures – Material specification”

Highways Agency

Highways England - DMRB - Specification for Highways Works

Transport Research Laboratory Report TRL630 New Continuously Reinforced Concrete Pavement Designs

ASTM Standards

ASTM C1231/C 1231M Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength