INSTITUTE OF CONCRETE TECHNOLOGY
CONCRETE TECHNOLOGY & CONSTRUCTION
Stage 4
ADVANCED CONCRETE TECHNOLOGY
Learning objectives Revision 1

4.00.00 Introduction to the course
4.00.01 Outline the aims, objectives and content of the course.
4.00.02 State methods of teaching and learning to be used on the course.
4.00.03 Plan for career progression following successful completion of the course.

4.01.00 Health and safety
4.01.01 Plan and manage a health and safety programme for concrete production, making reference to appropriate regulations.
4.01.02 Discuss common risks associated with concrete production and construction sites and state methods for minimizing sources of danger.

4.02.00 Sustainability (with acknowledgement to BRE Global Ltd)
4.02.01 Describe ways in which concrete contributes to reduction of embodied carbon dioxide.
4.02.02 Demonstrate how embodied carbon dioxide is calculated for concrete.
4.02.03 Plan an environmental management system for materials sourcing, concrete production or construction.
4.02.04 Explain how any conflicts between sustainability and concrete quality may be resolved.
4.02.05 Describe life cycle analysis as applied to concrete buildings and structures.

4.03.00 Cements
4.03.01 Name and describe the chemical compounds present in Portland cement and state the effects of each compound on the properties of concrete.
4.03.02 State and explain the influences of the properties of different types of Portland cement on the properties of concrete made with them.
4.03.03 Explain the principal chemical and physical processes of cement hydration.
4.03.04 Describe the composition and structure of the principal cement hydration products.
4.03.05 Describe in outline routine methods of chemical analysis of cement.
4.03.06 Name and describe in outline the techniques used to study hydration of cement.
4.03.07 Describe the manufacture of calcium aluminate (high alumina) cement, state the chemical composition, explain the process of hydration and explain the process of conversion.
4.03.08 Describe the properties of calcium aluminate cement concrete and state its applications.

4.04.00 Additions to concrete
4.04.01 State the uses for each addition in concretes, mortars and grouts.
4.04.02 State the physical and chemical characteristics of each addition and list the differences between it, Portland cement, and other additions.
4.04.03 Discuss the advantages and disadvantages of different forms of silica fume.
4.04.04 Explain how each addition is produced and describe how variations in raw materials and production affect the chemical and physical characteristics of the material.

4.04.05 Explain the differences between the use of each addition as a separate component in concrete and as one component of blended cements.
4.04.06 State the requirements of British and European Standards governing each addition and describe the methods of test, including the standard equivalence procedures.
4.04.07 Describe the reaction mechanism between each addition and Portland cement and other activators, as appropriate, during the hydration process and describe the composition and structure of the hydration products of each blend.
4.04.08 Describe and explain the effects which each addition has on the properties and characteristics of plastic, hardening and hardened concretes, mortars and grouts.
4.04.09 Describe the effect which each addition has on the performance of admixtures.
4.04.10 Select blends of each addition and Portland cement for particular situations and outline specification clauses appropriate to these situations.
4.04.11 Discuss the benefits and any special problems of combining additions in concrete.
4.04.12 Discuss the merits of multiple blends.

4.05.00 Admixtures

4.05.01 Name the ingredients of each type of admixture.
4.05.02 Explain the origins of admixtures and how they are manufactured or refined.
4.05.03 Distinguish between soluble, insoluble, adsorptive and interactive types of admixture.
4.05.04 Describe dissolution, dissociation and surface activity.
4.05.05 Explain the interaction of active cement mineral phases with admixtures.
4.05.06 Describe the main factors governing air bubble formation and stability when using air-entraining agents.
4.05.07 Explain the mechanism of the expansive processes during freezing and thawing in air- entrained concrete.
4.05.08 Describe the applications of plasticisers and superplasticisers in concrete and the ways in which they are used.
4.05.09 Compare the relationship between the dispersive action of plasticisers and that of air-entraining agents.
4.05.10 Describe the mechanism of accelerating admixtures in concrete.
4.05.11 Describe the mechanism of retarding admixtures in concrete.
4.05.12 Compare viscosity modifying admixtures with regard to their effect on pumped concrete.
4.05.13 Define the categories of waterproofing admixtures and describe their side effects.
4.05.14 Describe the mechanism of corrosion-inhibiting admixtures.
4.05.15 Describe the mechanisms of cement deactivators and deactivator neutralisers and their application in wash-water systems and in the re-use of returned concrete.
4.05.16 Describe the mechanism of anti wash-out admixtures to produce non-dispersible concrete for underwater work.
4.05.17 Describe the mechanism of foamed concrete admixtures.
4.05.18 Describe and review mortar and grout admixtures.
4.05.19 Describe the use of pigments in concrete.
4.05.20 Identify the effects which each type of admixture has on the properties of hardened concretes, mortars and grouts.
4.05.21 State reasons for importance of following the admixture manufacturer's instructions.
4.05.22 List the British and European Standards which apply to admixtures, state their requirements and methods of test for compliance.
4.05.23 Select suitable admixtures for given situations and outline specification clauses appropriate to those situations.

4.06.00 Aggregates

4.06.01 Relate petrological names of aggregates to the main sources of natural aggregates and their locations within the U.K.
4.06.02 Name and describe the principal techniques employed in petrographic examination of aggregates for concrete.
4.06.03 Correlate elementary mineralogy and petrology with the prediction of aggregate properties and the detection of potentially deleterious substances, during aggregate prospecting, quarrying and gravel extraction.
4.06.04 List the properties of aggregates and explain how the source and method of processing or production influence the characteristics and quality of aggregates.
4.06.05 Explain the importance of correct sampling of aggregates for testing and the effect of sampling on repeatability and reproducibility of the tests.

4.06.06 Explain how the properties of aggregates influence the properties of fresh and hardened concretes, mortars and grouts, including the effects of quality variations and of exceeding aggregate test limits.
4.06.07 Interpret aggregate test data and check compliance.
4.06.08 Relate aggregate types to applications and outline specification clauses appropriate to those applications.

4.07.00 Fresh concrete
4.07.01 Define rheology, Newtonian liquid and Bingham model and relate them to consistence.
4.07.02 Define consistence with respect to stability, mobility and compactibility.
4.07.03 Describe the British and European Standard test methods of measuring consistence and relate them to stability, mobility and compactibility.
4.07.04 Describe the two-point consistence test and its relationship to the Bingham model and compare standard tests on fresh concrete with two-point tests.
4.07.05 Describe how changes in material properties and proportions affect consistence, water demand and cohesion
4.07.06 Define and explain the bleeding of concrete and describe methods of control.
4.07.07 Describe the influences of consistence on the occurrence of segregation, bleeding, plastic settlement and plastic shrinkage.
4.07.08 Describe the features of materials, mix proportions, production process and the environment which influence the rate of stiffening of concrete and explain how the rate of stiffening can be increased or decreased.
4.07.09 State and explain the principles governing the correct placing, compaction and curing of concrete.

4.08.00 Setting and hardening:
4.08.01.00 <u>Plastic settlement and plastic shrinkage</u>
4.08.01.01 Describe how the various types of plastic settlement crack are caused.
4.08.01.02 Explain how factors such as concrete section and position and size of reinforcement affect the formation of settlement cracks.
4.08.01.03 Describe the effects and identify visible signs of plastic settlement (e.g. voids under steel).
4.08.01.04 Explain how to prevent or eliminate plastic settlement by revibration.
4.08.01.05 Describe the mechanism of plastic shrinkage and how its effects can be minimised.
4.08.01.06 Compare the effects of different materials on plastic shrinkage.
4.08.01.07 Identify the consequences of plastic shrinkage cracks, with particular reference to durability.
4.08.01.08 Explain criteria for selecting methods of repair for problems caused by plastic settlement and plastic shrinkage cracks.
4.08.02.00 <u>Exothermic characteristics under adiabatic conditions</u>
4.08.02.01 Define adiabatic conditions.
4.08.02.02 Compare the heats of hydration of different Portland cements and blends with additions.
4.08.02.03 Describe the influence of chemical admixtures on rates of heat evolution.
4.08.02.04 Calculate the rates of heat evolution for the most commonly used types of cement, given the necessary data.
4.08.02.05 Describe the methods used for measuring rates of heat evolution of cementitious materials.
4.08.02.06 Calculate the temperature rise in concrete for a given situation.
4.08.02.07 Explain the effects of hydration temperatures on the short and long term properties of concrete.
4.08.03.00 <u>Early age thermal movements</u>
4.08.03.01 Explain the causes of early age thermal cracking.
4.08.03.02 Recognise cracking due to restrained early age thermal contraction.
4.08.03.03 Describe the factors that affect early age thermal cracking.
4.08.03.04 Identify the practical actions that can be taken to reduce early age thermal cracking, in a specified set of circumstances.
4.08.03.05 Assess the likelihood of early age thermal cracking for a given set of circumstances.
4.08.04.00 <u>Strength development</u>
4.08.04.01 Describe the mechanism of strength development of concrete.
4.08.04.022 Compare the rates of strength development for concretes made with different materials.
4.08.04.03 Describe the effects of sub-normal and of elevated temperatures on the rate of strength development for different types of concrete.
4.08.04.04 Describe the effects of curing conditions on the rate of strength development of different concretes.

4.08.04.05 Describe methods for monitoring the rate of strength development of concrete in the laboratory and on site.
4.08.05.00 Concept of maturity
4.08.05.01 Explain the theoretical basis for the concept of maturity.
4.08.05.02 Compare formulae used for the determination of maturity and state advantages and disadvantages of each formula for different sets of circumstances.
4.08.05.03 Calculate the maturity of concrete in a given set of circumstances.
4.08.05.04 Design a curing cycle for a given set of circumstances, using the concept of maturity.
4.08.05.05 Describe methods of measuring data for determining maturity.
4.08.06.00 Accelerated curing
4.08.06.01 Explain the theoretical basis for accelerated curing.
4.08.06.02 Describe practical applications of accelerated curing for in situ and precast concrete.
4.08.06.03 Describe methods for the accelerated curing of concrete.
4.08.06.04 Describe the effects of accelerated curing on the properties of concrete.
4.08.07.00 Assessment of safe striking times
4.08.07.01 State and explain the main external factors that affect striking times for formwork and explain their significance.
4.08.07.02 Describe how concrete mix variations influence striking times.
4.08.07.03 Calculate safe striking times for a specific set of circumstances.
4.08.07.04 State the principal recommendations for striking of formwork given in Standard Specifications.
4.08.08.00 Cold weather concreting
4.08.08.01 Define cold weather concreting conditions, with reference to relevant Codes/Standards.
4.08.08.02 Describe the damaging effects of sub-zero temperatures on immature concrete.
4.08.08.03 Describe the effects of low temperatures on concrete during curing.
4.08.08.04 State and explain the effects of low temperatures on formwork striking times.
4.08.08.05 Define the basic principles of heat transfer and heat loss.
4.08.08.06 State and explain practical steps to be taken when concreting in cold weather.
4.08.08.07 State the levels of maturity at which concrete is considered to be safe from the damaging effects of sub-zero and low temperatures.
4.08.09.00 Hot weather concreting
4.08.09.01 Define hot weather conditions, with reference to relevant Codes/Standards.
4.08.09.02 Describe and explain the effects of hot weather on rates of bleeding of concrete and surface evaporation.
4.08.09.03 Calculate rates of surface evaporation under varying conditions of ambient temperature and wind speed.
4.08.09.04 Describe the practical methods which can be used to protect concreting materials and plant in hot weather conditions.
4.08.09.05 State the methods used on site to protect concrete during mixing, transporting and placing in hot weather.
4.08.09.06 Describe and explain the curing methods appropriate for hot weather conditions.

4.09.00 Properties of hardened concrete:

4.09.01.00 Strength
4.09.01.01 State the effect of shape of specimen on the measured compressive strength of concrete.
4.09.01.02 Explain the influence of lateral restraint upon measured strength.
4.09.01.03 Explain the factors affecting the porosity of the cement paste matrix in concrete.
4.09.01.04 Describe the effects of the porosity of the cement paste matrix upon the strength and modulus of elasticity of concrete.
4.09.01.05 Describe the shape of the stress/strain curve for concrete and compare it with that of other construction materials.
4.09.01.06 Describe methods used to measure the behaviour of concrete during loading.
4.09.01.07 Explain the shape of the stress/strain curve for concrete by consideration of the damage caused during loading.
4.09.01.08 Explain the effects of mix constituents on the strength, modulus of elasticity and stress/strain relationship for concrete
4.09.01.09 Describe the main methods of measuring tensile strength and state typical comparative values with compressive strength.

4.09.01.10 State the effect of moisture in the concrete on the measured strength of a specimen.
4.09.02.00 Movements
4.09.02.01 Explain the principal causes and main factors affecting creep and shrinkage deformation.
4.09.02.02 Indicate typical ranges of strain in concrete, which occur in practice.
4.09.02.03 Discuss the mechanisms of shrinkage and creep, with reference to current research.
4.09.02.04 Describe how shrinkage and creep are measured.
4.09.02.05 Describe the effects that shrinkage and creep may have upon concrete in service.
4.09.02.06 Estimate from given data the probable drying shrinkage and creep of concrete.
4.09.02.07 Describe how thermal and moisture movements in concrete are measured.
4.09.02.08 State and explain the practical effects of thermal and moisture movements on concrete in service.

4.10.00 Durability of concrete and concrete construction:

4.10.01.00 Durability concept
4.10.01.01 Review the phenomena that lead to durability failure in concrete.
4.10.01.02 Explain the concept of design life and outline the economic consequences of poor durability.
4.10.02.00 Forms of physical and chemical attack
4.10.02.01 Describe the various agencies which cause physical damage to hardened concrete.
4.10.02.02 Describe the various types of potential chemical attack on hardened concrete.
4.10.02.03 Differentiate between the basic mechanisms of physical and chemical attack.
4.10.03.00 Transport processes
4.10.03.01 State and explain the various ways in which aggressive agents can permeate concrete.
4.10.03.02 Explain the laws governing the rates of movement of liquids, vapours, gases and ions through hardened concrete.
4.10.03.03 Discuss the relevance of the permeation of hardened concrete to its durability.
4.10.03.04 Explain the main factors which determine the permeation properties of site concrete.
4.10.03.05 Describe and compare the various methods for measuring permeation properties of concrete.
4.10.04.00 Factors affecting reinforcement corrosion
4.10.04.01 Describe the nature of corrosion damage.
4.10.04.02 Describe in simple terms the basic mechanism of corrosion and state the main factors influencing corrosion rate.
4.10.04.03 Explain the terms "passivity" and "carbonation" and describe the conditions under which reinforcement in hardened concrete will remain passive and those in which it will not.
4.10.04.04 Describe the influence of chlorides on passivity and corrosion.
4.10.04.05 Explain the relationship between environmental conditions and risk of corrosion.
4.10.04.06 Describe and explain the influence of concrete composition, cover to reinforcement, curing and cracking on the likelihood of corrosion.
4.10.04.07 Describe and discuss appropriate detailing and construction measures for avoiding corrosion damage.
4.10.04.08 Describe the principles and methods of cathodic protection to inhibit reinforcement corrosion in concrete structures.
4.10.04.09 Describe the types of non-ferrous reinforcement available to combat structural deterioration.
4.10.05.00 Fire resistance
4.10.05.01 Describe the behaviour of structural concrete members in a fire and explain the mechanisms of damage.
4.10.05.02 Describe how fire damage to concrete is assessed.
4.10.05.03 State the advantages and disadvantages of structural concrete over other structural materials in fire resistant construction.
4.10.05.04 Describe the British Standard method for measuring fire resistance of concrete members and state how the data is used.
4.10.06.00 Deterioration due to freeze/thaw and de-icing salts.
4.10.06.01 Describe in outline the pore structure of cement paste and distinguish between evaporable and non-evaporable water.
4.10.06.02 State and describe the factors affecting the freezing and thawing resistance of concrete including the relevance of bubble size and spacing in determining the resistance of concrete to freeze-thaw attack.
4.10.06.03 Describe the effects of frost and de-icing salts on hardened concrete.

4.10.06.04 Outline the probable mechanisms by which deterioration of concrete due to freeze/thaw and de-icing salts occurs.
4.10.06.05 Describe the methods of testing the resistance of concrete to freeze/thaw and de-icing salts.
4.10.07.00 Acid, soft water and sulfate attack
4.10.07.01 Define "acid" and state methods used to classify acid solutions.
4.10.07.02 Describe the mechanisms of acid and soft water attack on concrete and mortar.
4.10.07.03 Describe the nature of the sulfate ion and mechanisms of sulfate attack on concrete including delayed ettringite formation and thaumasite formation.
4.10.07.04 Name the British Standards and other official publications which lay down procedures for specifying concrete for use in sulfate conditions.
4.10.07.05 Interpret classifications of soils and/or ground waters in terms of their sulfate contents.
4.10.07.06 Describe and explain the methods used to reduce the incidence of sulfate attack on concrete.
4.10.07.07 Describe the types of experiment on which specification limits for the use of concrete in sulfate conditions are based.
4.10.08.00 Alkali-silica reaction
4.10.08.01 Describe in outline the extent of the problem of alkali-silica reaction.
4.10.08.02 Describe alkali-silica reaction in concrete and the damage caused by it.
4.10.08.03 State the procedures for diagnosing that alkali-silica reaction is the likely cause of damage.
4.10.08.04 State the factors which can influence damage to concrete caused by alkali-silica reaction.
4.10.08.05 Explain the procedures which should be followed to minimise the risk of damage due to alkali-silica reaction, in a new structure.
4.10.08.06 Name the principal documents containing current recommendations for dealing with alkali-silica reaction and state their main recommendations.
4.10.09.00 Test methods for durability
4.10.09.01 Name and describe the British Standard test methods for determining concrete properties related to durability.
4.10.09.02 Describe field test methods currently in use on site for determining properties relating to the durability of concrete.
4.10.09.03 Explain the problems associated with accelerated testing for durability and predicting field behaviour from laboratory tests.

4.11.00 Mix design

4.11.01 Define "Strength class", "characteristic strength", "standard deviation", "margin" and "target mean strength" and state the relationship of one to another.
4.11.02 Identify the principal factors, and their interactions, which determine the performance of different materials in concrete.
4.11.03 State how the conflicting requirements for consistence, cohesion, strength and durability are resolved in the mix selection and proportioning processes.
4.11.04 Describe and compare methods of concrete mix design.
4.11.05 Design trial mixes for concretes containing Portland cement CEM I alone or in combination with one or more additions, using methods of mix design commonly in use.
4.11.06 Demonstrate how mix design can be carried out using a computer program.
4.11.07 Describe the preparation of a laboratory trial mix, the assessment of the mix and its adjustment. Note: see items 4.12.01 and 4.12.02 for mix design items for lightweight aggregate and high-strength concretes.

4.12.00 Special concretes

4.12.01.00 Light-weight concrete
4.12.01.01 Describe the production processes for aerated concretes.
4.12.01.02 State typical densities and strengths of aerated concretes and list other important properties.
4.12.01.03 Describe the production and uses of no-fines concrete.
4.12.01.04 State the typical densities and strengths of no-fines concrete and list other important properties.
4.12.01.05 Describe the different types of lightweight aggregate and their production.
4.12.01.06 State typical ranges of density and water absorption of lightweight aggregates.
4.12.01.07 Describe the properties of lightweight aggregate concrete.
4.12.01.08 Compare densities and strengths of concrete made from different types of lightweight aggregate.

4.12.01.09	Describe and explain mix design and production procedures for lightweight aggregate concretes.
4.12.01.10	State the effects of concrete density on the transmission of sound.
4.12.01.11	Compare the fire resistance and thermal cracking of lightweight aggregate concrete with that of normal concrete.
4.12.01.12	Compare the structural behaviour of lightweight and normal weight concretes.
4.12.01.13	State and explain the main factors affecting durability of lightweight aggregate concrete.
4.12.01.14	Compare the thermal insulation properties of the different types of lightweight concrete and relate them to natural dense aggregate concrete.
4.12.01.15	Describe the use of "U-values" and explain how they are derived for building elements.
4.12.01.16	Explain how the thermal conductivity of concrete is dependent upon its bulk density and moisture content.
4.12.01.17	State how thermal conductivity is measured.
4.12.01.18	Determine the U-value of a concrete building element.
4.12.02.00	<u>High strength concrete</u>
4.12.02.01	Describe how high strength concrete can be produced.
4.12.02.02	Explain why increases in cement content past a certain limit can lead to strength reduction.
4.12.02.03	State and explain the limiting effects of the properties of the aggregate on the strength of concrete.
4.12.02.04	Describe and explain the use of admixtures and additions in the production of high-strength concrete.
4.12.02.05	Describe how to determine the mix proportions for high strength concrete.
4.12.02.06	State the problems that can occur in transporting and placing high strength concrete and how they can be overcome.
4.12.02.07	State and explain the effects that the achievement of high strength can have on the other physical properties of the concrete.
4.12.03.00	<u>Refractory concrete</u>
4.12.03.01	Explain why calcium aluminate cement is used for refractory concrete.
4.12.03.02	State the types of aggregate suitable for refractory and high temperature heat- insulating concretes and describe their sources, manufacture and composition.
4.12.03.03	State typical mix proportions for refractory and high temperature heat-insulating concretes.
4.12.03.04	Select the appropriate type of refractory concrete for a given situation.
4.12.03.05	Describe the nature of the bond in refractory concretes.
4.12.04.00	<u>Heavy-weight concrete</u>
4.12.04.01	Identify the principal applications of high density concrete.
4.12.04.02	Describe the various sources of naturally occurring and man-made high density aggregates and outline their methods of production.
4.12.04.03	Describe the basic chemical, physical and mechanical properties of high density aggregates and concretes.
4.12.04.04	State and explain proportioning of materials for high density concrete.
4.12.04.05	Compare the requirements for storing and handling high density aggregates and producing, transporting and placing of high density concrete, with natural dense aggregate concrete.
4.12.04.06	Interpret specification compliance clauses for high density concretes.
4.12.05.00	<u>Polymer concrete</u>
4.12.05.01	List and describe the common types of polymer material used in cementitious systems.
4.12.05.02	Describe the methods of incorporating polymers into cementitious systems.
4.12.05.03	Describe the effects of polymers on the properties of concrete.
4.12.05.04	Describe the applications of polymer concretes.
4.12.06.00	<u>Fibre-reinforced concrete</u>
4.12.06.01	Describe the physical properties of the various types of fibre suitable for use in concrete.
4.12.06.02	Explain how fibres are incorporated into a concrete.
4.12.06.03	Describe how fibres modify the properties of both fresh and hardened concrete.
4.12.06.04	Describe the applications of fibre-reinforced concrete.
4.12.07.00	<u>Mortars and renders</u>
4.12.07.01	State the different designations of mortar in general use within the construction industry.
4.12.07.02	Describe the materials used for making mortar and their effects on the properties of the mortar.
4.12.07.03	Describe and compare methods of producing mortar.
4.12.07.04	Describe the tests to control the quality of fresh and hardened mortar.

4.12.07.05 Identify the problems associated with batching and placing mortar on site and state the requirements for good site supervision.
4.12.07.06 Explain the mechanisms of mortar failure.
4.12.07.07 Describe the practice of rendering of internal and external walls, using cement-based materials, with reference to substrate, mix proportions and application of the render.
4.12.07.08 Identify common defects related to the incorrect application of renders.
4.12.08.00 Recycled concrete
4.12.08.01 State the methods for recycling concrete and list its material properties.
4.12.08.02 Discuss the applications for concrete made from recycled material.
4.12.09.00 Foamed concrete
4.12.09.01 Describe the production processes and uses of flowing, low-density, low strength, foamed, void-filling concrete.
4.12.09.02 State typical densities of foamed concrete and list other important properties.
4.12.10.00 Miscellaneous products
4.12.10.01 Describe the composition, properties and applications of newly-developed products which are incorporated into concrete.

4.13.00 Special processes and technology for particular types of structure

4.13.01.00 Mass concrete
4.13.01.01 Explain what is meant by "mass concrete".
4.13.01.02 State and explain the factors influencing temperature rise in mass concrete.
4.13.01.03 Discuss the factors which determine the likelihood of cracking of mass concrete.
4.13.01.04 Describe how to control cracking in mass concrete.
4.13.01.05 Discuss the planning of a mass concrete pour.
4.13.02.00 Pumped concrete
4.13.02.01 Describe the flow of concrete through pipelines and compare with the flow of liquids.
4.13.02.02 Describe the types of concrete pump.
4.13.02.03 State the requirements of a concrete for pumping.
4.13.02.04 State and explain the effects that the aggregates, cement and admixtures have on the pumpability of concrete.
4.13.02.05 Describe the modifications which may be necessary to the concrete mix design to ensure pumpability.
4.13.02.06 Explain the significance of void content of aggregate and outline the procedures for measuring void content in combined aggregate grading.
4.13.02.07 Select a suitable combination of aggregates to produce a pumpable concrete in a given situation and differentiate between pumpable and unpumpable concrete.
4.13.03.00 Liquid retaining structures
4.13.03.01 State the requirements for specification of concrete materials and workmanship for liquid retaining structures.
4.13.03.02 Discuss durability requirements for concrete liquid retaining structures.
4.13.03.03 Describe the causes and control of cracking in concrete liquid retaining structures.
4.13.03.04 Describe methods of repairing leaks in liquid retaining structures.

4.13.04.00 Concrete coatings and surface treatments
4.13.04.01 Outline reasons why concrete surfaces may require further treatment.
4.13.04.02 Outline reasons for the presence on concrete surfaces of efflorescence, algal and other growths and describe methods of preventing them.
4.13.04.03 Review materials available for coatings and surface treatment.
4.13.04.04 Describe methods of surface preparation of concrete to receive coatings and surface treatments.
4.13.04.05 Describe methods of applying coatings and surface treatments to concrete

4.14.00 Ready-mixed concrete

4.14.01 Compare types of plant and equipment used for the production of ready-mixed concrete.
4.14.02 Describe precautions to be taken when producing ready-mixed mortar, lean concrete, lightweight concrete and air-entrained concrete.
4.14.03 State the effects of prolonged agitation on the properties of concrete.

4.14.04 Review developments in plant for the production, transport and control of ready-mixed concrete.
4.14.05 Describe how a concrete producer can ensure that a customer's mix descriptions are analysed and processed to meet the specification.
4.14.06 State the precautions to be taken when producing blended cement concrete.
4.14.07 Describe an effective control system to ensure that ready-mixed concrete meets performance specification requirements.
4.14.08 Recognise the importance of pre-planning stages and the co-ordination with all parties in the supply and placing of concrete to a contract.

4.15.00 Exposed concrete finishes
4.15.01 Describe the different types of both horizontal and vertical decorative concrete finishes.
4.15.02 Describe and explain the selection of materials and mixes and the methods of production for decorative concrete finishes.
4.15.03 Compare the weathering characteristics of the different types of concrete finish.
4.15.04 Describe the surface treatments used to give additional protection to concrete finishes.
4.15.05 Describe the various methods by which a client may communicate his requirements for a decorative finish.
4.15.06 Recognise the cost implications of producing decorative concrete finishes.

4.16.00 Repairing concrete
4.16.01 Prepare a schedule of test methods and frequency of testing required for the diagnosis and analysis of deterioration in typical concrete structures and environments.
4.16.02 List and describe the principal repair materials and discuss their benefits and limitations.
4.16.03 Describe methods of preparation and repair of concrete on site and discuss the limitations of each method.

4.17.00 Formwork
4.17.01 Recognise the importance of the formwork on the finished appearance of the concrete.
4.17.02 Describe the materials used for formwork and state their properties.
4.17.03 Describe factors which influence the pressures and forces on formwork.
4.17.04 Calculate formwork pressures given adequate data.
4.17.05 Explain how construction and striking requirements are taken into account in formwork design.
4.17.06 Describe types of form lining and state their applications.
4.17.07 State the function of release agents, describe the methods of using them and state precautions to be taken to avoid problems in their use.
4.17.08 Recognise the implications of civil engineering construction tolerances and the interface with mechanical plant tolerances.
4.17.09 Describe and state the reasons for use of controlled permeability formwork liners.

4.18.00 Concrete plant (No entries)

4.19.00 Precast concrete
4.19.01 Outline strength assessment requirements of current Codes.
4.19.02 Explain the nature of movement of concrete masonry walls and how provision is made for it.
4.19.03 Discuss the selection of mortars for concrete masonry

4.20.00 Concrete roads (No entries)

4.21.00 Industrial floors
4.21.01 Discuss the determination of slab thickness, flatness, bay size, joint locations and reinforcement requirements of ground floor slabs, taking into account the different types of loading.
4.21.02 Identify defects encountered in the manufacture and laying of floor screeds and toppings and outline appropriate remedial measures.
4.21.03 Describe the methods of test for floor screeds and carry out an assessment of the results of such tests.

4.22.00 Principles of reinforced and prestressed concrete

4.22.01 State and explain the main principles of structural design, viz. stability, safety, length of life and economy.
4.22.02 State and explain the different types of loading that can occur.
4.22.03 Explain how loads are transferred through a structure to the foundations.
4.22.04 Explain the principles of limit state design.
4.22.05 Distinguish between collapse and serviceability limit states.
4.22.06 Explain the use of partial safety factors in limit state design.
4.22.07 Describe and explain how a reinforced concrete beam behaves under load.
4.22.08 State the assumptions made in the design of a reinforced concrete section subjected to bending.
4.22.09 Outline the main methods of prestressing.
4.22.10 Outline the main factors which contribute to the loss of prestressing force and the methods of minimising that loss.
4.22.11 Name and explain the differences between types of reinforcement used for reinforced and prestressed concrete.
4.22.12 Outline good practice in the load-testing of simple structures.

4.23.00 Test methods and equipment:

4.23.01.00 General
4.23.01.01 List the British and European Standards for testing hardened concrete and the associated testing equipment, and state their principal requirements.
4.23.02.00 Testing machines
4.23.02.01 Define the basic requirements of a testing machine.
4.23.02.02 Describe the proving devices and procedures used for checking load indication and application.
4.23.02.03 Describe how the calibration of a testing machine is carried out.
4.23.02.04 List common faults which can occur on concrete cube testing machines.
4.23.02.05 List common faults by the operator of a concrete cube testing machine, which can lead to incorrect results.
4.23.02.06 State environmental requirements and daily care needed to obtain correct performance from a testir machine.
4.23.02.07 Describe a standard procedure for the verification of a testing machine by using a comparative cube test, giving reasons for the choice of strengths and cube size used in this test, or by other standard means.
4.23.02.08 Describe the effects of specimen on measured strength.
4.23.03.00 Accelerated and early age testing methods
4.23.03.01 State the aims and principles of accelerated and early age testing
4.23.03.02 Describe the equipment and procedures for the accelerated curing of test specimens.
4.23.03.03 Outline the applications of accelerated and early age testing
4.23.03.04 Discuss the use of accelerated and early age testing for control and conformity.

4.23.04.00 Analysis of hardened concrete and mortar
4.23.04.01 Outline the reasons for analysis of hardened concrete and mortar.
4.23.04.02 Describe the information that can be obtained from analysis.
4.23.04.03 Outline the procedures for sampling hardened concrete and mortar to achieve the required confidence in the results.
4.23.04.04 Outline the methods of analysis, giving the basis of the analytical procedures.
4.23.04.05 Discuss the factors influencing the precision and accuracy of results.
4.23.04.06 Discuss evaluation, interpretation and use of results.
4.23.05.00 Core drilling and testing
4.23.05.01 Outline the reasons for drilling and testing cores.
4.23.05.02 Describe the planning and preliminary work before drilling cores.
4.23.05.03 Describe the size and number of cores, location and drilling procedures for different situations.
4.23.05.04 Describe the visual examination, measurements and procedures which should be carried out prior to strength testing of cores.
4.23.05.05 Describe how to convert core strength results to in situ cube strength and potential strength, in accordance with Concrete Society Technical Report 11.

4.23.06.00 Non-destructive and partially-destructive testing

4.23.06.01 State the reasons for the non-destructive and partially destructive testing of hardened concrete and describe the methods of testing.

4.23.06.02 Discuss the factors governing choice of test.

4.23.06.03 Describe procedures for calibrating and operating equipment for the testing of concrete.

4.23.07.00 Assessment of concrete strength in structures

4.23.07.01 Discuss the factors affecting strength of concrete in structures.

4.23.07.02 Describe procedures for planning an investigation to assess the strength of hardened concrete based on BS6089 and/or Concrete Society Technical Report 11.

4.23.07.03 Select a suitable technique for assessing the strength of concrete in a structure.

4.23.07.04 Compare test methods used for assessing strength of concrete in structures.

4.23.07.05 Analyse the results of a non-destructive survey.

4.23.08.00 Analysis of fresh concrete

4.23.08.01 Describe situations where fresh concrete analysis might be used.

4.23.08.02 Describe methods of fresh concrete analysis.

4.23.08.03 Discuss the advantages and disadvantages of fresh concrete analysis.

4.23.08.04 State the principal requirements of the British Standard for analysis of fresh concrete.

4.23.09.00 Reinforcement investigation

4.23.09.01 Describe the use of electromagnetic covermeters in the determination of position and orientation of steel reinforcement and the depth of cover to steel.

4.23.09.02 Describe the equipment and procedures for determining the half-cell potential of reinforcement and explain how it can be used to assess steel corrosion.

4.23.09.03 Explain how concrete resistivity can be measured and reinforcement corrosion rate assessed.

4.23.09.04 Describe a simple method for determining the depth of carbonation in concrete.

4.24.00 Quality concepts

4.24.01 Define and distinguish between quality, quality management, quality assurance, quality systems and quality control.

4.24.02 State the principal EN ISO requirements for quality management systems and the principal recommendations national Standards relating to systems for concrete and its components.

4.24.03 List the principal benefits gained by the producer by introducing quality management systems.

4.24.04 List the principal benefits gained by the consumer from the introduction of quality assurance.

4.24.05 Describe how quality management functions in each sector of the concrete industry (from materials productio to construction) and state the principal requirements of approved QA schemes.

4.24.06 Describe product conformity certification.

4.25.00 Quality control

4.25.01 Name and explain the factors that influence the quality of the concrete construction product and classify their relative importance.

4.25.02 Explain what is meant by "quality", with reference to specification and fitness for purpose of the product.

4.25.03 Describe the problems involved in carrying out inspection, sampling, testing, interpretation of data and determination of action from the control system.

4.25.04 Select suitable quality control procedures for given situations.

4.26.00 Statistics

4.26.01.00 Introduction

4.26.01.01 Explain the difference between random and systematic influences on measurements.

4.26.01.02 Discuss the benefits and limitations of statistics in concrete technology.

4.26.01.03 Demonstrate an understanding of computer software packages and spreadsheets or statistical purposes

4.26.02.00 General terminology

4.26.02.01 Explain the terms "sampling distribution", "standard error", "large sample", "small sample", "significance level", "type I error" and "type II error".

4.26.02.02 Describe a "t" and an "F" distribution; define the term "confidence limit" and compute confidence

limits from a set of data.

4.26.03.00 Analysis

4.26.03.01 Carry out significance tests using normal, t and F distributions on specified parameter values and on differences between sample values.

4.26.03.02 Define the terms "linear regression", "curvilinear regression", "control variable", "response variable", "correlation" and "correlation coefficient".

4.26.03.03 For a set of data, determine an appropriate regression model, stating its limitations, and compute a correlation coefficient.

4.26.03.04 Sketch confidence limits about a regression line.

4.26.04.00 Experimental design

4.26.04.01 Explain the principles of experimental design.

4.26.05.00 Repeatability, reproducibility and uncertainty

4.26.05.01 Explain the terms "accuracy", "precision", "bias", "sampling variation" and "testing variation".

4.26.05.02 Define the terms "repeatability" and "reproducibility" and calculate values from given data.

4.26.05.03 Explain what is meant by "uncertainty".

4.26.06.00 Control charts

4.26.06.01 Explain the purpose of a control chart.

4.26.06.02 Define, construct and interpret Shewhart and Cusum charts.

4.26.07.00 Conformity testing

4.26.07.01 Explain the terms "producer's risk" and "consumer's risk".

4.26.07.02 Describe and explain an operating-characteristic (O-C) Curve.

4.26.07.03 Determine the producer's risk and consumer's risk from a given O-C Curve and the compliance clauses.

4.27.00 Standards, specifications and codes of practice

4.27.01 Identify the appropriate Standard for a particular aspect of concrete work.

4.27.02 Interpret a specification clause from a contract, covering any aspect of concrete technology.

4.27.03 Compare a contract specification with relevant Standard Specifications and identify any differences.

4.27.04 Discuss the relevance of current Standards to the present state of knowledge of concrete from research and practice.

4.28.00 Assessment of concrete construction

4.28.01 Describe how to carry out an investigation into the quality of the finished product.

4.28.02 Describe and explain common methods used for the site inspection of concrete.

4.28.03 Name the common causes of surface blemishes on concrete and explain how such defects can be avoided or minimised.

4.28.04 Interpret data collected during an investigation.

4.29.00 Sources of information

4.29.01 Carry out a search to locate relevant information on a topic in concrete technology.

4.29.02 Locate a particular publication from a given reference.

4.29.03 Summarise the key points from a technical article.

4.29.04 Collate and compare the findings from several papers on the same topic.

END OF STAGE 4