Unit 4: Science and Materials in Construction and the Built Environment

Unit code: T/600/0221

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit develops learner knowledge of the factors that affect human comfort, the performance criteria applicable to construction materials, and the techniques used to produce such materials. They will also gain an understanding of how forces act on structures, construction materials and the techniques used to prevent and remedy their deterioration.

Unit introduction

Two important functions of a building are to provide shelter and create a comfortable space in which to live or work. To achieve this, it is necessary to know about and understand the materials used to construct a building, the basic concepts that underpin the structural integrity of the building, and the design of the building's internal spaces.

The occupants of a building require a comfortable internal environment and there are several key factors that contribute to this. There are generally accepted ranges for these factors. Understanding what is acceptable to different end users who undertake a variety of tasks and activities is an essential requirement of good design.

The forces that act on buildings, the stresses generated by these forces and the effects of these stresses on the materials used to construct the building are also explored.

Materials may be used for their structural or insulating properties; others, for example conduct heat and/or electricity well. Learners will have the opportunity to investigate some of the typical materials used in their specific vocational pathway, including identifying the most important materials, a basic understanding of how they are extracted, harvested or manufactured, their key properties and uses, the mechanisms that cause them to deteriorate and the techniques used to prevent such deterioration.

Learning outcomes

On completion of this unit a learner should:

1 Know the basic factors that affect human comfort

2 Understand how forces act on structures

3 Know the performance criteria applicable to construction materials and the techniques used to produce such materials

4 Understand construction materials and the techniques used to prevent their deterioration.

Unit content

1 Know the basic factors that affect human comfort

Factors that affect human comfort: thermal, sound, illumination

Thermal factors: physical factors (air temperature; mean radiant temperature; relative humidity; air velocity); personal factors (eg age, gender, state of health, clothing, level of activity); methods used to measure physical factors (eg thermometers, globe thermometer, hygrometer, anemometer); acceptable range of values for each factor; standard units

Sound factors: loudness of sound; frequency of sound; intrusive sound; sound insulation; methods used to measure each factor (sound level meter); acceptable range of values for each factor; standard units

Illumination factors: level of artificial lighting; level of natural lighting; glare; methods used to measure each factor (eg light meter, daylight meter); acceptable range of values for each factor; standard units

2 Understand how forces act on structures

Structural members: struts; ties; beams; columns; walls; frames

Underpinning concepts: loadings (dead loads; imposed loads; wind loads); forces (concurrent; non-concurrent; coplanar); load configurations (point; uniformly distributed); stresses (compression; tension; bending, shear)

Predicting structural behaviour: calculations to determine important factors (eg stress, strain, modulus of elasticity, factor of safety; simple beam reactions for point loads and uniformly distributed loads); graphical methods (triangle of forces; parallelogram of forces) to solve simple frames

3 Know the performance criteria applicable to construction materials and the techniques used to produce such materials

Performance criteria relating to the specification: fitness for purpose; visual appearance; costs; resistance to degradation; ease of installation or use; environmental implications; sustainability and recycling potential; COSHH considerations; compatibility

Construction materials relevant to the learner's vocational pathway: eg limes; cements; aggregates; concrete; gypsum plasters; timber; metals; paints; bricks; plastics; liquids (especially water); gases (especially air)

4 Understand construction materials and the techniques used to prevent their deterioration

Features and properties: strength; elasticity; porosity and water absorption; thermal and moisture movement; thermal and electrical conductivity/resistivity; thermal transmittance (U values); durability; workability; density; specific heat capacity; viscosity

Deterioration: corrosion; electrolytic action; fungal attack; insect attack; frost attack; chemical attack; sulphate attack; efflorescence; ultraviolet (UV) attack; stress; fatigue; role of water in failure mechanisms

Preventive and remedial techniques: as applicable to the construction materials specified in learning outcome 3 above

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 describe the basic factors in simple scientific terms that influence human comfort in the internal environment [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]	**M1** produce clearly worked, accurate answers for three different calculations relating to human comfort in the internal environment	**D1** analyse, in both qualitative and quantitative terms, the basic factors that affect human comfort
P2 describe how each factor is measured [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]		
P3 state acceptable values for each factor [IE1, IE2, IE4, IE6, CT1, SM3]		
P4 interpret underpinning concepts relating to structures under load [IE1, IE2, IE4, IE6, CT1, RL3, RL4, TW1, TW6, SM3]	**M2** produce clearly worked, accurate answers for three different problems involving simple structures under load	
P5 predict simple structural behaviour from given data [IE1, IE2, IE4, IE6, CT1, RL3, RL4, TW1, TW6, SM3]		

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P6 identify the main performance criteria relating to the specification of a range of vocationally relevant construction materials [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]	**M3** make and support valid decisions relating to the specification of materials for a tutor-provided application.	**D2** evaluate preventative and remedial techniques applicable to the failure of materials.
P7 describe the production and/or manufacturing processes for two vocationally relevant construction materials [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]		
P8 describe the important features and properties of construction-related materials [IE1, IE2, IE4, IE6, CT1, RL3, RL4, TW1, TW6, SM3]		
P9 explain how construction materials can deteriorate in use [IE1, IE2, IE4, IE6, CT1, RL3, RL4, TW1, TW6, SM3]		
P10 explain the preventive and remedial techniques used to prevent deterioration of construction materials. [IE1, IE2, IE4, IE6, CT1, RL3, RL4, TW1, TW6, SM3]		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills which are embedded in the assessment of this unit. By achieving the criteria, learners will have demonstrated effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, supervised practicals, research using the internet and/or library resources and use of personal and/or industrial experience are all suitable. Delivery should stimulate, motivate, educate and enthuse learners. Visiting expert speakers could add to the vocational relevance of the subject.

Learning outcomes 1 and 2 are not linked, either to each other or to learning outcomes 3 and 4. Learning outcomes 3 and 4 *are* linked and form a logical, consistent and progressive structure. This suggests an approach based on three broad areas of delivery.

It is important to contextualise delivery of learning outcomes 3 and 4 so that learners study only those materials that are used within their specific vocational pathway and that underpin their choice of specialist units. It is, therefore, anticipated that centres will identify, at the start of the programme, the materials and the properties of those materials that are most relevant to the specific vocational needs of their learners and to the other units being studied.

Teaching and learning strategies designed to support delivery of the learning outcomes should take an integrated approach and combine learner-centred investigative techniques with supervised, hands-on experiential learning. Practical activities should be used whenever possible. This would involve learners taking measurements, making observations, consulting standards, making decisions and suggesting alternatives.

Calculations are implicit in several aspects of the unit in general and in learning outcomes 1 and 2 in particular. The unit should not however be seen as a mathematical exercise and delivery should a balance the calculations and the knowledge and understanding implicit within the learning outcomes. Calculations used to support the delivery process should always reflect real life and standard practices.

This unit provides the fundamental principles that will underpin the learning outcomes of several other units, and it should be undertaken at an early stage in the programme. The learning outcomes can be integrated into a progressive delivery programme, as an underpinning introduction to associated learning outcomes in other units.

Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

Health, safety and welfare issues are paramount and should be reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken before practical activities are taken. Centres are advised to read the *Delivery approach* section in the specification.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction to unit Factors that affect human comfort thermal, air quality, sound and illumination – whole-class, tutor-led discussion Techniques used to measure factors – small group activity with each group being allocated one factor, presentation of findings to whole-class, Q&A session, use of standard equipment where available Acceptable range of values for each factor – individual research
Assignment 1: Human Comfort
Forces and structures structural members, loadings, forces, load configurations, stresses – whole-class, tutor-led delivery with practical demonstrations of effect of forces on structures, supported by practical learner activities if appropriate equipment available Calculations – tutor to demonstrate exemplar calculations and learners to practice by performing similar calculations, with emphasis on amending incorrect answers after first assessment and using correct units at all times Graphical solutions– tutor to demonstrate exemplar graphical solution and learners to practise by performing similar exercises, with an emphasis on amending incorrect answers after first assessment and accurate drawing at all times
Assignment 2: Forces and Structures
Materials criteria for specification – whole-class, tutor-led discussion of important criteria such as strength, elasticity, porosity, water absorption, moisture movement, durability, workability, visual appearance, cost, resistance to degradation and interaction with other materials; learners to complete simple table of these properties for the common construction materials, rating each as good (✓), average (?) or poor (x) Production and manufacture – small group activity with each group being allocated one material, presentation of findings to whole-class, Q&A session Properties in use – hands-on use of materials library, materials testing and discussion of results where appropriate equipment is available Deterioration and failure – hands-on use of materials library and images of deterioration of materials and components Small group activity with each group being allocated one mode of deterioration, presentation of findings to whole-class, Q&A session Preventive and remedial techniques – use of materials library and internet to research preventive and remedial techniques, small group activity with each group being allocated one technique, presentation of findings to whole-class, Q&A session
Assignment 3: Construction Materials
Unit review and assignment feedback

Assessment

Evidence for this unit may be gathered from a variety of sources, including well-planned investigative assignments, case studies or reports of practical assignments.

There are many suitable forms of assessment that could be used and some examples of assessment approaches are suggested below. However, these are not intended to be prescriptive or restrictive, and are provided as an illustration of the alternative forms of assessment evidence that would be acceptable.

Some criteria can be assessed directly by the tutor during practical activities. If this approach is used suitable evidence would be observation records or witness statements. Guidance on the use of these is provided on the Pearson website.

To obtain a pass learners must achieve all 10 pass criteria.

For P1, learners must be able to describe a minimum of four of the factors that influence an individual's overall perception of comfort in the internal environment. These should include factors from the thermal, acoustic and visual environment. Learners are expected to know how these factors affect the individual's perception of comfort but they are not, at this stage, required to demonstrate a detailed understanding of the mechanisms by which an individual interacts with the internal environment. Evidence could, for example be in the form of a presentation.

For P2, learners must be able to describe the basic methods by which each of the factors described in P1 are measured. Learners must use the correct units for each variable. At this stage learners do not need to perform calculations. Evidence for this criterion could, for example, be in the form of a presentation or a report using text, tables, images and graphs as appropriate.

For P3, learners must be able to state acceptable values for each of the identified factors. Specific values are acceptable but so is a range of acceptable values. Correct units should be used at all times.

For P4, learners must be able to interpret the important concepts associated with forces acting on structural members. Learners do not need to quantify wind loads but they must be aware of the difference between dead loads, imposed loads and wind loads and know what is implied by each of these terms. Similarly, learners should understand what is meant by the terms concurrent, non-concurrent and coplanar forces, and point and uniformly-distributed loads. Learners must be able to differentiate between compressive, tensile, shear and bending stresses, and must demonstrate an awareness of how stresses always alter the shape of loaded members and how excessive stresses may lead to failure. Examples of suitable approaches to evidence are as for P1.

For P5, learners must predict simple structural behaviour from given data. This could include the way structures change shape due to compression, tension, shear and bending, bending stresses that imply compression, tension and shear stresses all at once, and the difference between positive and negative shear and positive and negative bending for simply supported beams and cantilevers. A general qualitative understanding is sufficient and no calculations are required unless used to reinforce a qualitative point. Evidence for this criterion could, for example, be in the form of a presentation or the results of a practical exercise using text, tables, images and graphs as appropriate.

For P6, learners must identify the performance criteria that contribute to the specification of a range of given construction-related materials. It is important that the materials considered are relevant to the learner's vocational pathway and reflect the range of materials they will encounter in other specialised units. Materials may be solids, liquids or gases, and may be composite or homogeneous. Learners are expected to identify the most important criteria for each material in terms of how these relate to performance-in-use. Examples of suitable approaches to evidence are as for P5.

For P7, learners must describe the production and/or manufacturing processes used to produce two vocationally relevant construction materials. The manufacturing processes can be kept simple but should emphasise in general terms the energy expended in extraction, harvesting, transport and manufacturing. Examples of suitable approaches to evidence are as for P5.

For P8, learners must describe the most important features and properties of construction related materials that are relevant to the learner's vocational pathway and reflect the range of materials they will encounter in other specialised units. It is anticipated that learners from construction, civil engineering and building services engineering pathways will consider different groups of materials with different properties. Learners must differentiate clearly between each property, define what each means, and use the correct units as appropriate. Examples of suitable approaches to evidence are as for P5.

For P9, learners must explain the mechanisms by which these materials fail in use. Failure mechanisms should also be vocationally relevant as outlined above. Examples of suitable approaches to evidence are as for P5.

For P10, learners must explain how the failure mechanisms identified in P9 can be prevented or remedied. Examples of suitable approaches to evidence are as for P5.

To achieve a merit grade learners must achieve all of the pass criteria and the three merit grade criteria.

For M1, learners must produce clear and accurate answers for three different calculations associated with the factors of the internal environment that affect human comfort. The calculations should refer to thermal and air quality, sound and illumination respectively and could deal with topics such as mean radiant temperature, relative humidity, dewpoint temperatures, the relationship between decibel, sound intensities and sound pressures, the relationship between the candela, the lumen and the lux and so on, but care should be taken to relate the calculations to the unit specification and **not** cover the content of either *Unit 13: The Underpinning Science for the Provision of Human Comfort in Buildings* or *Unit 33: Building Services Science*. The answers to these calculations should be substantially correct, but small errors in calculation are acceptable provided they are corrected after feedback from the tutor. Evidence could be provided as the results of a practical exercise using tables, graphs and calculations as appropriate.

For M2, learners must produce clear and accurate answers for three simple structural problems. This should comprise two calculations and one graphical solution relating to problems associated with simple structures under load. One of the calculations should involve the determination of simple beam reactions and the other should relate to stresses, strains, moduli of elasticity and factors of safety as applied to either a strut under compression or a tie under tension. The graphical solution should relate to either triangles or parallelograms of forces for a frame with a minimum of three members. Examples of suitable approaches to evidence are as for M1.

For M3, learners must make and support valid decisions relating to the specification of given vocationally relevant applications. Decisions must be supported by reference to the features and properties of the materials and required performance criteria for the particular application. If necessary decisions should be supported by appropriate calculations to demonstrate performance standards or achievement of performance criteria. Examples of suitable approaches to evidence are as for P1.

To achieve a distinction grade learners must meet all of the pass criteria and merit grade criteria and the two distinction grade criteria.

For D1, learners must analyse the basic factors that affect human comfort. This should include a basic discussion of how the thermoregulatory system is affected by air temperature, mean radiant temperature, relative humidity, air speed, rates of air change, activity and clothing level to create the perception of thermal comfort; how specific values for the factors that affect the visual environment interact with the vision system to allow us to perform tasks, and how specific values of the aural environment interact with hearing systems to allow us to concentrate and make the space fit for purpose. The analysis should include comment on the acceptability of comfort parameters for given locations. This may be either an analysis of the suitability of given parameters for various locations or by recommending and justifying values for the various parameters for given locations.

For D2, learners must evaluate techniques capable of preventing the failure of the vocationally relevant materials and failure mechanisms identified in P10. The preventative action should include a range of appropriate approaches and techniques using materials, including avoidance of failure situations, treatment to increase a material's resistance to the causes of failure, remedial actions to prevent further deterioration, etc. The various techniques should be evaluated in terms of effectiveness, ease of application, cost, health and safety and environmental friendliness.

Programme of suggested assignments

The following table shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the grading grid. This is for guidance and it is recommended that centres write their own assignments or adapt any Pearson assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, P4, M1, D1	Human Comfort	A property developer is converting an old warehouse into modern office accommodation. The client is keen to make the working environment for the staff as comfortable as possible. As a consultant, explain how this can be done by addressing the relevant grading criteria.	Presentation and/or report supported by calculations, graphs, tables, images and text as appropriate.
P4, P5, M2	Forces and Structures	The property developer does not know about structural mechanics and is looking for an introduction to the subject based upon the conversion of an old warehouse to modern office accommodation. As a consultant, use simple examples from the conversion to show how forces act on structures.	Presentation and/or report supported by calculations, graphs, tables, images and text as appropriate.
P6, P7, P8, P9, P10, M3, D2	Construction Materials	The client does not know about construction materials and is looking for an introduction to why certain materials have been specified and how they resist degradation. As a consultant, use simple examples from the conversion to show how this is achieved.	Presentation and/or report supported by calculations, graphs, tables, images and text as appropriate.

Links to other BTEC units

This unit forms part of the BTEC Construction and the Built Environment sector suite. This unit has particular links with the following unit titles in the Construction and the Built Environment suite:

Level 1	Level 2	Level 3
		Unit 2: Sustainable Construction Unit 3: Mathematics in Construction and the Built Environment Unit 6: Building Technology in Construction Unit 10: Surveying in Construction and Civil Engineering Unit 33: Building Services Science

Essential resources

Resources should include the equipment needed to measure factors associated with human comfort including thermometers, (mercury-in-air, globe, Kata), hygrometers, anemometers, sound level meters, light meters and daylight meters. In general, instruments and items of equipment are available at a realistic cost and centres will not need to buy the best available equipment for learners to achieve the learning outcomes.

A short programme of practical activities will help with delivery of the structural mechanics element of the unit. Suitable rigs can be devised from simple, readily available equipment.

'Hands-on' experience of vocationally relevant materials is considered essential and a library of materials should be readily available to learners. Testing of these materials is not essential but, where equipment is available, it will help learners develop a better understanding of how usage follows properties.

Health, safety and welfare issues must be considered at all times and risk assessments should be undertaken for all demonstrations and experiments used in the delivery or assessment of this unit.

Employer engagement and vocational contexts

Support to enable centres to initiate and establish links to industry, and to networks arranging visits to industry and from property practitioner is given below:

- Learning and Skills Network
- National Education and Business Partnership Network
- The Royal Institution of Chartered Surveyors

Delivery of personal, learning and thinking skills (PLTS)

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	identifying questions to answer and problems to resolve, planning and carrying out research, analysing and evaluating information and supporting conclusions using reasoned arguments and evidence, as they: • identify the basic factors that influence human comfort in the internal environment • describe in simple scientific terms the basic factors that influence human comfort in the internal environment • describe how each factor is measured • state acceptable values for each factor • interpret important concepts relating to simple structures under load • predict simple structural behaviour from given data • identify the main performance criteria relating to the specification of a range of vocationally relevant construction materials • describe the production and/or manufacturing processes for two vocationally relevant construction materials • identify the important features and properties of a range of construction-related materials • analyse the important features and properties of a range of construction-related materials • explain the mechanisms by which construction materials can fail in use
Creative thinkers	generating ideas and exploring possibilities, as they: • identify the basic factors that influence human comfort in the internal environment • describe in simple scientific terms the basic factors that influence human comfort in the internal environment • describe how each factor is measured • state acceptable values for each factor • interpret important concepts relating to simple structures under load • predict simple structural behaviour from given data • identify the main performance criteria relating to the specification of a range of vocationally relevant construction materials • describe the production and/or manufacturing processes for two vocationally relevant construction materials • identify the important features and properties of a range of construction-related materials • analyse the important features and properties of a range of construction-related materials • explain the mechanisms by which construction materials can fail in use

Skill	When learners are ...
Reflective learners	reviewing progress, acting on the outcomes, inviting feedback and dealing positively with praise, setbacks and criticism, as they: • identify the basic factors that influence human comfort in the internal environment • describe in simple scientific terms the basic factors that influence human comfort in the internal environment • describe how each factor is measured • state acceptable values for each factor • interpret important concepts relating to simple structures under load • predict simple structural behaviour from given data • identify the main performance criteria relating to the specification of a range of vocationally relevant construction materials • describe the production and/or manufacturing processes for two vocationally relevant construction materials • identify the important features and properties of a range of construction-related materials • analyse the important features and properties of a range of construction-related materials • explain the mechanisms by which construction materials can fail in use
Team workers	collaborating with others to work towards common goals, as they: • interpret important concepts relating to simple structures under load • predict simple structural behaviour from given data • analyse the important features and properties of a range of construction-related materials • explain the mechanisms by which construction materials can fail in use

Skill	When learners are ...
Self-managers	organising time and resources and prioritising actions, as they: • identify the basic factors that influence human comfort in the internal environment • describe in simple scientific terms the basic factors that influence human comfort in the internal environment • describe how each factor is measured • state acceptable values for each factor • interpret important concepts relating to simple structures under load • predict simple structural behaviour from given data • identify the main performance criteria relating to the specification of a range of vocationally relevant construction materials • describe the production and/or manufacturing processes for two vocationally relevant construction materials • identify the important features and properties of a range of construction-related materials • analyse the important features and properties of a range of construction-related materials • explain the mechanisms by which construction materials can fail in use.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using the internet to research into human comfort and construction materials
Manage information storage to enable efficient retrieval	collating research material for use in presentations and reports
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	using the internet to research into human comfort and construction materials
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	using the internet to research into human comfort and construction materials
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	producing presentational material and reports for assessment purposes
Bring together information to suit content and purpose	
Present information in ways that are fit for purpose and audience	
Evaluate the selection and use of ICT tools and facilities used to present information	
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	exchanging information, communicating by email and attaching and opening attachments to emails
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	exchanging information, communicating by email and attaching and opening attachments to emails
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	performing calculations relating to human comfort conditions and the effects of forces acting on structures
Identify the situation or problem and the mathematical methods needed to tackle it	
Select and apply a range of skills to find solutions	
Use appropriate checking procedures and evaluate their effectiveness at each stage	
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	
Draw conclusions and provide mathematical justifications	

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	making presentations and contributing to question and answer sessions afterwards
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and collating information for presentations and reports
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing reports for assessment purposes.