

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

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

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

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, and an understanding of what is acceptable to a variety of different end-users, undertaking 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 properties, or for their insulating properties; others conduct heat and/or electricity well, for example. Learners will have the opportunity to investigate some of the typical materials used in their specific vocational pathway, including the identification of the most important materials, a basic understanding of how these 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, and an acceptable range of values for each factor
- 2 Understand how forces act on simple structures
- 3 Know the performance criteria applicable to a range of vocationally relevant construction materials, and the techniques used to produce such materials
- 4 Understand the properties of construction materials, how such materials deteriorate and the techniques used to prevent their deterioration.

Unit content

1 Know the basic factors that affect human comfort, and an acceptable range of values for each factor

Thermal and air quality: nature of heat; heat transfer; thermal comfort in terms of activity; clothing; room temperatures; air movement; humidity and ventilation; condensation; measurement of various factors; standard units; acceptable comfort parameters; basic calculations

Sound: nature of sound; sound levels; nature of hearing; measurement of noise; noise control; noise transfer; sound insulation; standard units; acceptable parameters; basic calculations

Illumination: nature of vision; simple colour rendering; need for daylight; measurement of lighting; standard units; acceptable parameters for natural and artificial light; basic calculations

2 Understand how forces act on simple structures

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

Loadings: dead loads; imposed loads; wind loads

Forces: concurrent and non-concurrent; coplanar

Load configurations: point; uniformly distributed

Stresses: compression; tension; bending and shear

Calculations relating to: stresses; strains; moduli of elasticity; factors of safety; simple beam reactions for point loads; and uniformly distributed loads

Graphical methods: triangle of forces; parallelogram of forces for simple frames

3 Know the performance criteria applicable to a range of vocationally relevant construction materials, and the techniques used to produce such materials

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

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

4 Understand the properties of construction materials, how such materials deteriorate and the techniques used to prevent their deterioration

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. As appropriate to the materials associated with the learner's vocational pathway

Deterioration and failure: corrosion; electrolytic action; fungal attack; insect attack; frost attack; chemical attack; sulphate attack; efflorescence; ultra-violet (UV) attack; stress; fatigue; role of water in failure mechanisms. As appropriate to the materials associated with the learner's vocational pathway

Preventive and remedial techniques: as applicable to the modes of deterioration and failure of materials associated with the learner's vocational pathway

Grading grid

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

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 identify and describe each of the basic factors that influence human comfort in the internal environment; describe how each factor is measured, and state acceptable values for each factor	M1 produce clear and accurate answers to three different calculations relating to human comfort in the internal environment	D1 analyse and discuss, in both qualitative and quantitative terms, the basic factors that affect human comfort
P2 define and interpret important concepts relating to simple structures under load	M2 produce clear and accurate answers to two different problems involving simple structures under load	
P3 predict simple structural behaviour from given data		
P4 describe the main performance criteria relating to the specification of a range of vocationally relevant construction materials including, as appropriate, basic details of the production and/or manufacturing processes	M3 make and support valid decisions relating to the specification of materials for a tutor-specified application, using given design data and using calculations where appropriate.	D2 evaluate a range of preventative and remedial techniques applicable to the failure of materials appropriate to the learner's vocational pathway.

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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:
P5 identify and describe the most important features and properties of a range of construction-related materials and the mechanisms by which these materials can fail in use.		

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 the 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 relevance of the subject.

Learning outcomes 1 and 2 are not linked, either to each other or to learning outcomes 3 or 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 the 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 clearly identify, at the start of the programme, both 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 to be 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 the delivery should provide a balance between 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 many other units, and it should be undertaken at an early stage of the programme. The learning outcomes from this unit are suitable for use in an integrated 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 are provided with equal experiential and assessment opportunities.

Health, safety and welfare issues are paramount and should be strictly reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken prior to practical activities. Centres are advised to read the *Delivery* approach section on page 24, and *Annexe G: Provision and Use of Work Equipment Regulations 1998 (PUWER)*.

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 employed. Some examples of possible 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. General guidance on the design of suitable assignments is available on page 19 of this specification.

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 Edexcel website.

The structure of the unit content suggests that the grading criteria may be fully addressed by using three assignments. The first of these would cover P1, M1 and D1, the second would cover P2, P3 and M2 and the third would cover P4, P5, M3 and D2.

To achieve a pass grade learners must meet the five pass criteria listed in the grading grid.

For P1, learners must be able to identify and describe the factors of the internal environment that affect an individual's overall perception of comfort. These should include the factors of the thermal, acoustic and visual environment and should include a description of the basic methods by which each factor is measured. Learners must use the correct units for each variable. At this stage there is no need for learners to perform calculations. Learners are expected to know that these factors affect the individual's perception of comfort but they are not, at this stage, required to demonstrate an understanding of the mechanisms by which an individual interacts with the internal environment. Evidence for this criterion could be provided, for example, in the form of a presentation or as the results of a practical exercise using text, tables, images, graphs and calculations as appropriate.

For P2, learners must be able to state the important concepts associated with forces acting on structural members. There is no need for learners to quantify wind loads but they must be aware of the difference between dead loads, imposed loads and wind loads and they should know what is implied by each of these terms. In a similar fashion, 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 evidencing approaches are as for P1.

For P3, learners must demonstrate a general understanding of how forces affect the behaviour of structures. This could include the way structures change shape due to compression, tension, shear and bending, how bending stresses imply compression, tension and shear stresses all at once, and the difference between positive and negative shear and positive and negative bending for both 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 be provided, for example, in the form of a presentation or as the results of a practical exercise using text, tables, images and graphs as appropriate.

For P4, learners must identify and describe the criteria that contribute to the specification of a range of given construction-related materials. It is important that the materials considered are materials relevant to learner's vocational pathway and reflect the range of materials which they will encounter in other specialised units. The materials may be solids, liquid or gases, and may be composite or homogeneous. Learners are expected to identify the most important criteria for each material and show how these relate to performance-in-use. Details of manufacturing processes can be kept simple but should emphasise the energy expended in extraction, harvesting, transport and manufacturing in general terms. Examples of suitable evidencing approaches are as for P3.

For P5, learners must identify and describe the most important features and properties of a range of construction materials. It is important that the materials and properties considered are those relevant to learner's vocational requirements and reflect the range of materials which 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 clearly differentiate between each property, define what each means, and use the correct units as appropriate. Learners must also identify the ways in which these materials fail in use. Failure mechanisms should also be vocationally relevant as outlined above. Examples of suitable evidencing approaches are as for P3.

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

For M1, learners must present a minimum of three 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 forth, but care should be taken to relate the calculations to the unit specification and **not** intrude upon the content of either *Unit 13: Environmental Science in Construction* 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 for this criterion could be provided as the results of a practical exercise using tables, graphs and calculations as appropriate.

For M2, learners must present a minimum of 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 calculation 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 simple frames. Examples of suitable evidencing approaches are as for M1.

For M3, learners must select and specify appropriate materials for 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 the decisions should be supported by appropriate calculations to demonstrate performance standards or achievement of performance criteria. Examples of suitable evidencing approaches 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 be able to analyse and discuss the quality of the internal environment, the effectiveness of given internal environments at maintaining human comfort and the mechanisms by which comfort is maintained. This should include a basic explanation of how the thermo-regulatory 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 by 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 compare and evaluate a variety of techniques and procedures capable of preventing the failure of the vocationally relevant materials and failure mechanisms identified in P5. 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 compared in terms of effectiveness, ease of application, cost, health and safety and environmental friendliness.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit provides the underpinning principles and understanding contained in several other units at National level, for example *Unit 13: Environmental Science in Construction*, *Unit 33: Building Services Science*, *Unit 34: Heating in Building Services Engineering* and *Unit 35: Ventilation and Air Conditioning in Building Services Engineering*. Learning outcomes 3 and 4 provide underpinning knowledge for several other units where materials for various applications are specified. The unit also provides progression to units in environmental science and building services at Higher National and degree level.

This unit may have links to the Edexcel Level 3 Technical and Professional NVQs for Construction and the Built Environment. Updated information on this, and a summary mapping of the unit to the CIC Occupational Standards, is available from Edexcel. See *Annexe D: National Occupational Standards/mapping with NVQs*.

The unit provides opportunities to gain Level 3 key skills in application of number; and communication. Opportunities for satisfying requirements for Wider Curriculum Mapping are summarised in *Annexe F: Wider curriculum mapping*.

Essential resources

Resources should include the equipment necessary 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 very best equipment available to achieve the learning outcomes.

A short programme of practical activity will help 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 the learners. Testing of such materials is not considered 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 the unit.

Indicative reading for learners

Textbooks

Burberry P – *Environment and Services* (Longman, 1997) ISBN 0582245214

McMullan R – *Environmental Science in Building* (Palgrave Macmillan, 2001)
ISBN 0333947711

Smith P and Sweeney – *Environmental Science* (Longman, 1997) ISBN 0582416205

Taylor G D – *Materials in Construction: An Introduction* (Longman, 2000)
ISBN 0582368898

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Staff should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	They should be able to develop the following key skills evidence:
<ul style="list-style-type: none"> producing clear and accurate answers to a variety of calculations relating to human comfort in the internal environment producing clear and accurate answers to a variety of problems involving simple structures under load making and supporting valid decisions relating to the specification of materials from given design data using calculations where necessary. 	<p>N3.1 Plan an activity and get relevant information from relevant sources.</p> <p>N3.2 Use your information to carry out multi-stage calculations to do with:</p> <ul style="list-style-type: none"> a amounts or sizes b scales or proportion c handling statistics d using formulae. <p>N3.3 Interpret the results of your calculations, present your findings and justify your methods.</p>

Communication Level 3	
When learners are:	They should be able to develop the following key skills evidence:
<ul style="list-style-type: none"> • identifying and describing the range of factors of the internal environment that influence human comfort and the methods used for measuring such factors • defining and interpreting important concepts relating to simple structures under load • describing the main criteria related to the specification of a range of vocationally-relevant construction materials and where appropriate, the details of the production and/or manufacturing processes • identifying, defining and describing the important features and properties of a range of construction related materials and the mechanisms by which these materials can fail in use • analysing and discussing in a qualitative and quantitative way, the factors that affect human comfort • evaluating a range of preventative and remedial techniques applicable to the failure of materials appropriate to the vocational pathway. 	<p>C3.1a Take part in a group discussion.</p> <p>C3.1b Make a formal presentation of at least eight minutes using an image or other support material.</p> <p>C3.2 Read and synthesise information from at least two documents about the same subject. Each document must be a minimum of 1000 words long.</p> <p>C3.3 Write two different types of documents, each one giving different information about complex subjects. One document must be at least 1000 words long.</p>