Unit 52: Structural Analysis and Design in Construction

Unit code: A/600/0334

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim of this unit is to enable learners to develop an understanding of design structures and skills in designing structural elements in timber, in-situ reinforced concrete and steel.

Unit introduction

The study of structural analysis and design is essential for engineers, architects and contractors to enable them to design and build structures safely. The unit aims to give learners the knowledge and understanding required to analyse and design structural elements to the appropriate British Standard or European Code of Practice. In this unit, learners would be able to understand design requirements as contained in the design briefs, specifications and relevant codes. The unit deals with structural elements in timber, in-situ reinforced concrete and steel which are not covered in other related units in terms of analysis and design. The unit also includes analysis and design of indeterminate structures in accordance with design codes and industrial practice. Learners will develop a deeper understanding of the structural elements as well as of the suitability of structural materials to be used in a given structural form.

It is recommended that this unit is delivered at a later stage in the programme when learners have completed the units *Structural Mechanics in Construction and Civil Engineering* and *Further Mathematics in Construction, Civil Engineering and Building Services Engineering*.

The unit will also provide learners with a sound basis for learning how to analyse and design more complex structures at a higher level.

Learning outcomes

On completion of this unit a learner should:

1 Understand the concepts and data required to design structures

2 Be able to design structural elements in timber

3 Be able to design structural elements in in-situ reinforced concrete

4 Be able to design structural elements in steel.

Unit content

1 Understand the concepts and data required to design structures

Structural concepts: shear force and bending moments; loading and support conditions; beams, frames and columns; determinate and indeterminate structures; conditions of equilibrium; degree of indeterminacy; redundancy

Design requirements: serviceability; British Standards; European Codes of Practice; design brief; specifications, material selection

2 Be able to design structural elements in timber

Structural elements: single-grade glued laminated beam; ply-webbed I-beam; load-bearing timber stud partition

Analysis: strength classes; service classes; magnitude and duration of loading; bearing and shear stress; conditions of equilibrium; theorem of three moments; permissible stress design; load factor design; limit state design

Design: form factor; depth factor; slenderness; selection of suitable section size

3 Be able to design structural elements in in-situ reinforced concrete

Structural elements: continuous beams; one-way spanning slabs

Analysis: theorem of three moments; beams over two and three spans; beams over unequal spans; approximate analysis; permissible stress design; load factor design; limit state design

Design: reinforcement details including diameter, spacing and overlaps; bonding and anchorage; cover required; fire resistance

4 Be able to design structural elements in steel

Structural elements: restrained beams eg fixed, pinned, propped; rigid frames eg portal frames

Analysis: slope deflection method; moment distribution method; inflection points; permissible stress design; load factor design; limit state design

Design: suitable sections; connection details

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 assessment 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 discuss the structural concepts and design data required to carry out structural design [SM3]		
P2 analyse structural elements to ascertain their adequacy [SM3]		
P3 produce a suitable section size for a single-grade glued laminated beam [IE4]		
P4 produce a suitable design for a load-bearing timber stud partition		
P5 analyse structural elements made from in-situ reinforced concrete [SM3]	**M1** explain methods of analysing in-situ reinforced concrete continuous beams in the light of current standards	
P6 produce designs for structural elements in in-situ reinforced concrete [IE4]		**D1** evaluate the effects of a design brief on the final design of in-situ reinforced concrete structural elements
P7 analyse structural elements in steel [IE3]	**M2** explain the effects of restraints on the structural behaviour of a steel beam.	
P8 design structural elements in steel. [IE2]		**D2** evaluate alternative methods to analyse a rigid frame in steel.

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key			
	IE – independent enquirers CT – creative thinkers	RL – reflective learners TW – team workers	SM – self-managers 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, videos/DVDs, 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.

Learning outcome 1 is intended to develop an understanding of the design requirement of a structure and the need to ensure that structures are designed in accordance with design briefs, specifications and relevant codes.

Learning outcome 2 deals with the design of structural elements in timber. Learners will be introduced to glued laminated timber and ply-webbed I-beams as well as load-bearing stud partitions. The emphasis should be on the accurate determination of the parameters so that these members can be designed safely. An understanding of the structural properties of timber is paramount and calculations involving complex loading systems should be avoided.

Learning outcome 3 deals with the design of structural elements in in-situ reinforced concrete. The emphasis should be on learners appreciating the difference between determinate and indeterminate structures and its influence on analysis and design. Learners will be introduced to one-way spanning slabs and continuous beams. The emphasis should be on accurate analysis so that these members can be designed safely. Calculations involving complex loading systems should be avoided.

Learning outcome 4 deals with the design of structural elements in steel. Learners will be introduced to restrained beams which, though not continuous, are indeterminate and require different techniques to analyse and design. Learners will also analyse and design rigid-jointed frames. The emphasis should be on accurate analysis so that these members can be designed safely. Calculations involving complex loading systems should be avoided.

The emphasis should be on learners following industry standards in terms of level of detail, accuracy and conventions.

Learners should be encouraged to work through problems related to real-life situations so that they become familiar with the application of calculations to real structures. Once the design for an element of a structure has been clarified, the tutor's role should be supporting rather than directing. Learners should be encouraged to study recent completed drawings and designs so that they become familiar with current practice.

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

Health, safety and risk management should be integrated into all aspects of this unit.

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, and *Annexe H: Provision and Use of Work Equipment Regulations 1998 (PUWER)*.

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
Tutor input: introduction to the unit
Tutor input: review of important structural concepts: shear force and bending moments; Loading and support conditions; beams, frames and columns
Tutor input: determinate and indeterminate structures; conditions of equilibrium; degree of indeterminacy; redundancy
Class discussion: design requirements: design brief
Didactic input: design requirements: serviceability; British Standards; European Codes of Practice; design brief; specifications, material selection
Learner exercise: choosing a structural form and material for a given design brief
Tutor input: analysis methods; determinate structures; review of elastic and limit state design methods
Structural elements in timber
Tutor input: review: types and properties of timber
Tutor input: stress grading and strength classes of timber
Class discussion: factors affecting timber strength
Tutor input: introduction to glued laminated timber
Didactic input: analysis and design of glued laminated timber beam: geometric properties; K factors, trial sections, bending stress, lateral stability
Learner exercise: formative assessment exercise – design of a single-grade glued laminated timber beam
Didactic input: analysis and design of ply-webbed I-beam – geometric properties; K factors, deflection, panel shear and rolling shear
Learner exercise: formative assessment exercise – design of a ply-webbed I-beam
Didactic input: analysis and design of stud walls – axial compression and combined loading, load sharing and end-restraints; geometric properties; K factors, selection of sections
Learner exercise: formative assessment exercise – design of load-bearing stud walls
Preparation for assignment
Assignment 1: Structural Elements in Timber

Topic and suggested assignments/activities and/assessment
Structural elements in in-situ reinforced concrete
Tutor input: bending moments for continuous beams – theorem of three moments
Tutor input: analysis of continuous beams with two equal spans
Learner exercise: computation of forces, bending moments and construction of diagrams
Tutor input: analysis of continuous beams with unequal spans
Learner exercise: computation of forces, bending moments and construction of diagrams
Tutor input: analysis of continuous beams over three spans
Learner exercise: formative assessment exercise – computation of forces, bending moments and construction of diagrams
Tutor input: approximate analysis of continuous beams
Tutor input: introduction to slabs
Tutor input: one-way and two-way spanning slabs; dimensional considerations
Tutor input with whole-class exercise: reinforcement requirements: identification of reinforcement areas; minimum and maximum spacing; fire resistance; and cover required.
Learner exercise: formative assessment exercise – design of a one-way spanning slab
Preparation for assignment **Assignment 2: Structural Elements in Concrete**
Structural elements in steel
Tutor input: restrained beams – inflection points
Tutor input: analysis of restrained beams
Learner exercise: formative assessment exercise – computation of forces, bending moments and construction of diagrams
Tutor input: introduction to rigid-jointed frames, rotation and deflection
Didactic input: moment distribution method: sign convention, fixed-end moments
Learner exercise: computation of bending moments at the joints and lateral deflection
Didactic input: slope deflection method – deflected shapes, sign convention and notation
Learner exercise: computation of bending moments at the joints and lateral deflection
Preparation for assignment **Assignment 3: Structural Elements in Steel**
Review of unit delivery and assessment

Assessment

It is recommended that evidence for learning outcomes is achieved through well-planned course work, assignments and projects. Assessment may be formative and summative and both may feature as part of the process.

Many suitable forms of assessment can be used and tutors are encouraged to consider and adopt these where appropriate. Some example 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.

The structure of the unit suggests that the grading criteria could be addressed fully by using three assignments. The first of these would cover P1, P2, P3 and P4, the second would cover P5, P6, M1 and D1 and the third P7, P8, M2 and D2.

To achieve a pass grade learners must meet the eight pass criteria.

For P1, learners must discuss the structural concepts and design requirements of a structure. They should refer relevant codes and a given design brief. Evidence could be in the form of a well-referenced written report.

For P2, learners must analyse structural elements to ascertain design adequacy. Emphasis should be given to accurate and logical presentation of calculations and results. Evidence should be presented as calculations and diagrams.

For P3, learners must produce a suitable section size for a single-grade glued laminated beam. Emphasis should be given to accurate and logical presentation of calculations and results. Evidence should be presented as calculations and diagrams.

For P4, learners must produce a suitable design for a load-bearing timber stud partition. Emphasis should be given to accurate and logical presentation of calculations and results. Evidence should be presented as calculations and diagrams.

For P5, learners must analyse structural elements in in-situ reinforced concrete. This should include continuous beam and one-way spanning in-situ reinforced concrete. They should be able to analyse beams over equal and unequal spans as well as over three spans. Emphasis should be given to accurate and logical presentation of calculations and results. Evidence should be presented as calculations and diagrams.

For P6, learners must produce suitable designs for structural elements (members) in in-situ reinforced concrete. This should include continuous beam and one-way spanning in-situ reinforced concrete. The data could be from P5. They should be able to produce design details such as bar diameters, spacing, overlaps and bondage. Emphasis should be given to accurate and logical presentation of calculations and results. Evidence should be presented as calculations and diagrams.

For P7, learners must analyse structural elements (members) in steel. These should include restrained beams and rigid frames. They should be able to analyse at least two types of restraints. They should be able to carry out the analysis either by moment distribution or slope deflection method. Emphasis should be given to accurate and logical presentation of calculations and results. Evidence should be presented as calculations and diagrams.

For P8, learners must produce suitable designs for structural elements in steel. These should include restrained beams and rigid frames. The data could be provided from P7. They should be able to produce design details such as section and connection details. Emphasis should be given to accurate and logical presentation of calculations and results. Evidence should be presented as calculations and diagrams.

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

For M1, learners must explain methods of analysing in-situ reinforced concrete continuous beams in the light of current standards. At least two methods should be explained. Evidence could be in the form of a report supported by appropriate details.

For M2, learners must explain the effects of restraints on the structural behaviour of a steel beam. Evidence could be in the form of a report supported by diagrams.

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

For D1, learners must evaluate the effects of a design brief on the final design of in-situ reinforced concrete structural elements (members). Learners should work to a case study or tutor brief taking into account exposure conditions, durability and performance in fire. Evidence could be in the form of a report supported by diagrams, calculations and data extracted from relevant codes.

For D2, learners must evaluate alternative methods used to analyse a rigid frame in steel. The emphasis should be on the application of these methods. This can be set as an extension to the activity for P8. Evidence could be in the form of a report supported by appropriate details.

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 either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, P4	Structural elements in timber	You are working as a trainee junior technician in a design consultancy. You have been asked by your senior engineer to carry out an analysis and design of some structural elements in timber. The relevant data is provided.	A report on design requirements and containing design solutions for a given design brief.

Criteria covered	Assignment title	Scenario	Assessment method
P5, P6, M1, D1	Structural elements in concrete	You are working as a trainee junior technician in a design consultancy. You have been asked by your senior engineer to carry out an analysis and design of some structural elements in in-situ reinforced concrete. The relevant data is provided. Your Senior Engineer has also advised you to compare the alternative methods used to analyse such elements and evaluate the changes in the design brief as detailed below.	A report containing design solutions for a given design brief as well as an explanation and evaluation.
P7, P8, M2, D2	Structural elements in steel	You are working as a trainee junior technician in a design consultancy. You have been asked by your senior engineer to carry out an analysis and design of some structural elements in steel. The relevant data is provided. Your senior engineer has also advised you to explore the effects of restraints and an evaluation of alternative methods used to analyse such elements.	A report containing design solutions for a given design brief as well as an explanation and evaluation.

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

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
		Science and Materials in Construction and the Built Environment
		Structural Mechanics in Construction and Civil Engineering
		Construction in Civil Engineering
		Structural Behaviour and Detailing for Construction

This unit links to the following Level 3 NOS:

- BE Design
- BE Development and Control
- Construction Contracting Operations.

Essential resources

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

Employer engagement and vocational contexts

The use of vocational contexts is essential in the delivery and assessment of this unit. Much of the work can be set in the context of case studies of local employers. Visits to companies/shows/exhibitions will enhance this particular part of the unit.

Learners should have access to recently completed drawings and designs so that they become familiar with current practice and standards of presentations.

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

- Learning and Skills Network – www.vocationallearning.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- The Royal Institution of Chartered Surveyors – www.rics.org
- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI University of Warwick) – www.warwick.ac.uk/wie/cei/

Indicative reading for learners

Textbooks

Anthony A et al – *Reynolds's Reinforced Concrete Designer's Handbook, 11th Edition* (Taylor and Francis, 2007) ISBN 0419258302

Durka F et al – *Structural Mechanics: Loads, Analysis, Design and Materials, 6th Edition* (Prentice Hall, 2002) ISBN 0582431654

Fiona C – *Structural Engineer's Pocket Book, 2nd Edition* (Butterworth-Heinemann, 2008) ISBN 0750686863

Hulse R and Cain J – *Structural Mechanics, 2nd revised Edition* (Palgrave Macmillan, 2000) ISBN 0333804570

McKenzie W – *Design of Structural Elements* (Palgrave Macmillan, 2003) ISBN 1403912246

Mosley H – *Reinforced Concrete Design, 6th revised Edition* (Palgrave, 2007) ISBN 0230500714

Ozelton E – *Timber Designers' Manual* (Wiley Blackwell, 2006) ISBN 1405146710

Seward D – *Understanding Structures: Analysis, Materials, Design, 3rd Revised Edition* (Palgrave Macmillan, 2003) ISBN 0333973860

Smith P – *An Introduction to Structural Mechanics* (Palgrave Macmillan, 2001) ISBN 0333962559

Steel Construction Institute – *Steel Design Manual, 6th Edition* (Wiley Blackwell, 2005) ISBN 1405134127

Websites

www.Structuralconcepts.org	Seeing and Touching Structural Concepts

Delivery of personal, learning and thinking skills (PLTS)

The following table identifies the PLTS opportunities that have been included within the assessment criteria of this unit:

Skill	When learners are ...
Independent enquirers	planning and carrying out research to evaluate alternative methods used to analyse a rigid frame explaining alternative methods used to analyse in-situ reinforced concrete beams using, analysing and evaluating design information, judging its relevance and value
Self-managers	organising time and resources and prioritising actions when evaluating affects of design brief on the final design.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Creative thinkers	trying out alternative or new design solutions
Reflective learners	assessing their own design solutions by applying safety checks
Self-managers	using standard procedures to carry out analysis and design.

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	
Use ICT to effectively plan work and evaluate the effectiveness of the ICT system they have used	
Manage information storage to enable efficient retrieval	
Follow and understand the need for safety and security practices	
Troubleshoot	
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	evaluating design methods for a given design brief
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	
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	preparing reports and presenting results of their analysis/design
Bring together information to suit content and purpose	
Present information in ways that are fit for purpose and audience	presenting evidence of analysis and design of structural elements.
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	

Skill	When learners are ...
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	calculating forces and moments in a beam with different restraints
Identify the situation or problem and the mathematical methods needed to tackle it	calculating moment of area and section modulus
Select and apply a range of skills to find solutions	determining magnitude and type of forces in an indeterminate frame
Use appropriate checking procedures and evaluate their effectiveness at each stage	applying stability checks to the final design
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	determining the size of a beam with different constraints
Draw conclusions and provide mathematical justifications	evaluating alternative analysis and design methods
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	explaining alternative analysis methods
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	explaining alternative methods of designing structural members in the light of British Standards.
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	