



Unit 29: Principles and Applications of Structural Mechanics

Delivery guidance

The focus during the delivery of this unit should be on developing the knowledge and skills that will enable learners to understand how structures behave under load, and to solve relevant structural mechanics problems.

Approaching the unit

This is an optional unit for learners taking the BTEC International Level 3 Diploma and Extended Diploma in Civil Engineering. Throughout delivery, tutors can engage learners by relating the content of this unit to industry projects or work carried out in other units of the qualification. When starting teaching, the emphasis should be on how the skills that are developed in this unit are transferable across a variety of construction and engineering sectors, and how they will support learners during higher education, as well as in various job roles.

Illustrations, images, animations and video clips are all useful resources to explain how loads are carried and transmitted through various structural elements. Such resources are often available online and can be easily incorporated into any tutor presentation.

Invite guest speakers from structural design, geotechnics and environmental engineering, or experts from higher education institutions, who could help learners understand the importance of skills learned in this unit for further study and satisfactory performance in various job roles.

Delivering the learning aims

Throughout delivery, the content of this unit should relate to a number of units in this qualification, which will help to motivate learners.

Learning aim A

Learning aim A is about understanding the types of structural members and how these behave under various loading conditions. This learning aim gives the underpinning knowledge required to develop skills in structural mechanics.

The sessions could start by introducing how several types of loads act on structures. Make full use of animations, DVDs, pictures, illustrations or web-based videos. Then introduce concepts such as compression, tension, deflection, stress and strain. For commonly used structural materials (e.g. steel, timber and reinforced concrete), lead a tour of the campus buildings and ask learners to identify the structural materials that they can see.

Once learners have grasped these concepts, introduce how the behaviour of structural members can be shown graphically, and explain their impact on structural design. Engage learners by demonstrating examples, such as loading types, types of forces and loading configurations, and then give learners activity sheets with which they can practise developing these skills.

Introduce calculations related to section properties, as well as for stress, strain, modulus of elasticity and the factor of safety.



Challenge and support learners during unit delivery through knowledge quizzes, paired or small group activities and class discussions. These will give learners opportunities for peer learning.

Learning aims B and C

Learning aim B is concerned with the analysis of beams, columns and frames. It should be emphasised that this analysis gives an essential base for the design, which is covered in learning aim C.

You could adopt a holistic, project-based approach, where the delivery of learning aims B and C could be combined, as these have a significant overlap in terms of their content. Learners could complete a project which will give them an opportunity to demonstrate the skills to analyse beams, columns and frames, as well as to design beams, columns and a mass retaining wall. You could contact structural engineering consultancies and specialists in order to obtain analysis and design examples.

Introduce the learning aims by solving examples in a step-by-step manner. You could produce a range of worksheets covering beams, columns, frames and retaining walls so that learners can practise the analysis techniques. An example project could be used, which learners could then analyse and design.

Learning aim D

You could deliver learning aim D through a tutor-led research activity. Explore opportunities where learners could visit an industry partner or a technology exhibition, and use this to support both delivery and assessment of this learning aim.

It is important to have access to relevant project information, such as drawings, especially those related to layout, material specifications and loading conditions.

Finally, where possible, invite a guest speaker from a design background. The guest speaker should be able to share with learners the current approaches and design practices in the industry.



Assessment model

Learning aim	Key content areas	Assessment approach
A Understand the principles of structural behaviour under load	A1 Concepts A2 Simple structural behaviour from given data	A presentation or written report to clearly explain, with the aid of diagrams and supporting calculations, the underpinning concepts relating to how structural elements behave under loads.
B Carry out calculations to solve structural mechanics problems	B1 Beams B2 Columns B3 Frames	A report containing calculations and interpretation of results for contextualised structural element tasks subject to loading conditions.
C Undertake the design of structural elements	C1 Beam design C2 Column design C3 Retaining wall design	A report containing written responses on design methods and their suitability, and production of design solutions for a given design brief. A report or presentation for a given project scenario that evaluates the measures used to protect and enhance land and buildings.
D Examine the use of computers in structural analysis and design	D1 Computer software packages for design calculations D2 Benefits and drawbacks of using computing software	A written review for a journal on structural design, read by structural and civil engineers, of the impact of computer software on computer structural analysis and design.



Assessment guidance

There is a maximum of three summative assignments for this unit. The assignment briefs should be set within the context of a small design project.

For Assignment 1, which will cover learning aim A, adequate details should be given in order to interpret the behaviour of structural elements under load, such as the size of members and loading conditions. You should ensure that learners are sufficiently supported. Part of the assessment could be completed under laboratory conditions, where learners could interpret the behaviour of structural elements under load.

For Assignment 2, which will cover learning aims B and C, a design brief should be included with drawings and material specifications, so that the learners can carry out their own analysis and undertake design. Learners should refer to credible sources of information while evaluating alternative design approaches.

Assignment 3 is essentially a research exercise that uses web-based resources or requires attending an event, where learners can carry out an evaluation of the structural software available. Assessment evidence may take the form of a project report and a portfolio, containing learner analysis and design calculations, as well as evidence of research. Ask learners, as part of the instructions, to include sketches, illustrations and a list of information sources used.



Getting started

This gives you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 29: Principles and Applications of Structural Mechanics

Introduction

Introduce learners to the unit using animations, DVDs, pictures, illustrations or web-based videos relating to structural mechanics and structural engineering.

Engage learners during the delivery of this unit through knowledge quizzes, paired or small group activities, class discussions and research work, as well as through guest speakers and visits to technology exhibitions.

Learning aim A – Understand the principles of structural behaviour under load

Learning aim A1

- Deliver a presentation to introduce the topic by showing animations or short video clips. Use simple terms to explain how structural elements behave under different loading conditions, and the resulting stress within the element.
- Continue the presentation by using animations, DVDs, pictures, illustrations or web-based videos to introduce concepts such as structural members, tension, compression, stress, strain and deflection.
- Ask learners to form into pairs for a practical activity. Take learners on a campus tour and give them a checklist with which they can identify each type of structural member they see in a particular location, as well as the material used for the members. Have learners complete the list in pairs and then present to the rest of the group during a class discussion. Give support, drawing on common judgement errors, and summarise learners' findings.
- Carry out a learning check using a knowledge quiz and assess learning through peer assessment. Ask learners to reach the correct answers through a class discussion, giving support where necessary.

Learning aim A2

- Facilitate a tutor-led class discussion to introduce how the behaviour of structural members could be shown graphically. Include deflected shapes of beams and columns, and engage learners through a Q&A session.
- Ask the learners to form into small groups and give each group one example of a beam and a column. Ask each group to discuss, research and draw the deflected shape. Learners are then to justify their findings as a group to their peers. Drawing on key points, give support, where appropriate, and summarise learners' findings.
- Through tutor demonstration, introduce calculations related to section properties, stress, strain, modulus of elasticity and factor of safety. Engage learners through a Q&A session. Use a knowledge quiz to check learning before asking learners to start calculations.
- Ask learners to form into pairs and complete a number of activity sheets for the calculations as mentioned previously. Give model answers, asking learners to complete a self-assessment, and give constructive and developmental feedback.
- To review learning across this topic, facilitate a class discussion, interpreting the behaviour of structural members under load. Summarise learner feedback and



expand on key points as necessary.

Learning aim B – Carry out calculations to solve structural mechanics problems

Learning aim C – Undertake the design of structural elements

Learning aims B1 and C1

- Develop a project brief or obtain one from a design consultancy. There must be adequate details for learners to analyse and design the required structural members, such as structural drawings, layout and material specifications.
- The sequence of delivery would be such that the delivery of learning aim B1 could be followed by learning aim C1, so that both the analysis and design of beams are covered.
- For the delivery of learning aim B1, introduce the different types of support and the way the beams are classified. Use illustrations, animations and pictures of projects showing the ways in which beams could be supported. Engage learners through a Q&A session.
- Introduce the concept of point loads and distributed loads by making a reference to the self-weight of beams. It is important at this stage to introduce the sign conventions used to show loading on the beams, as well as the way that the beam is supported.
- Through a tutor demonstration (and starting an example of a beam with point load), show how support reactions are calculated. Follow the same example to plot the shear force and bending moment diagram for this beam. Engage learners by asking them to do calculations, thereby helping to solve the example.
- Organise a class discussion about the relationship between shear force and bending moment. Introduce the concept of contraflexure and the relationship between the point of zero shear and maximum bending moment. Give learners an example of beams with overhangs, as well as cantilever beams that are under various load configurations. Ask them to work in small groups to estimate the deflected shape of these beams. Give support, drawing on key points, and summarise learner findings.
- Demonstrate how beams with overhangs and cantilever beams could be analysed. Engage learners in calculations and through a Q&A session.
- Ask learners to form into pairs to complete a number of activity sheets, analysing them to produce shear force and bending moment diagrams. Include simple to complex load configurations that include both point loads and uniformly distributed loads for differentiation purposes, in order to cater for the varying ability among learners. Give support and draw on common learner errors, such as value of shear and bending at free ends. Give model answer sheets so that learners are able to develop a clear understanding of how structural calculations are to be presented.
- For the delivery of learning aim C1, demonstrate to learners some examples of a steel beam design (as it is generally straightforward to deal with), which will help give learners confidence as they develop their design skills. Give learners extracts from relevant parts of the steel manual, so that they can find out the dimensions themselves. Emphasise the relationship between analysis and design by highlighting how the maximum bending moment, as well as section properties, have been used in design.
- Deliver a presentation to introduce the concept of limit states in design. The focus should be on the ultimate limit state at this level. Follow this with the design of the same beam in timber, as well as in reinforced concrete. Throughout the presentation, refer to relevant British and/or local standards.



- Using the example design project and tutor-led group activity, ask learners to carry out the design of beams. Different beams, in terms of their position within the structure, could be assigned to learners in small groups and/or based on the structural materials. For example, one group could design the same beam in steel, while the other could do this in reinforced concrete. Give support to calculate loads on the beams. Learners should then present their designs to the rest of the class in their groups, justifying the design recommendations made.

Learning aims B2 and C2

- Introduce the delivery of learning aim B2, followed by learning aim C2. For learning aim B2, introduce the concept of axial and eccentric loading, using a tutor-led class discussion. Draw on learners' existing knowledge, gained through their experience of designing beams.
- Then deliver a presentation about the effective length and slenderness ratio, and the relationship between the two elements. Using illustrations, highlight the difference between a long and a short column.
- Give learners a knowledge quiz to assess their understanding of key terminology, drawing on the key points, and summarise.
- Develop a number of task sheets covering design exercises for columns that are related to the example project. Demonstrate some example calculations before handing these to the learners, and support learners while they are working on solving the tasks. This activity could also be conducted in small groups.

Learning aim B3

- Use a knowledge quiz to start the delivery of learning aim B3. The quiz should recap the concepts related to loads and structural member types.
- Show examples of how to work out determinacy of a frame, while highlighting the difference between statically determinate and indeterminate structures. Follow this with a tutor demonstration to work through three methods of analysing a frame, including the graphical method. Engage learners by involving them in calculations, as well as through a Q&A session.
- Using the example design project and tutor-led group activity, assign each group with a typical frame. For example, groups could be allocated a roof truss, a structural frame or a truss bridge. Give support to steer the group initially. Have learners present their work to the rest of the class in their groups, justifying the design recommendations made.

Learning aim C3

- Use a tutor presentation to introduce the delivery of learning aim C3. This part of the unit draws on knowledge across the unit, and hence should be delivered after other analysis and design work has been undertaken.
- Using illustrations and pictures, show learners various types of retaining walls and the purpose of each type. Demonstrate to learners the factors required to design a mass retaining wall, with example calculations to check a wall against sliding, overturning and overstressing. Engage learners by involving them in calculations, as well as through a Q&A session.
- Using the example design project and tutor-led group activity, ask learners to design and apply checks for a given retaining wall. Ensure that you give learners all the data, such as loads, materials and surcharge values. Give support to determine the section size and to calculate loads. Once complete, learners can present to the rest of the class in their groups, justifying the design recommendations made. Give learners constructive and



developmental feedback.

- To review learner knowledge across these learning aims, facilitate a class discussion to evaluate the alternative design methods, and approaches to calculate loads and determine section sizes. Draw on key points and summarise.

Learning aim D - Examine the use of computers in structural analysis and design

Learning aim D1

- To introduce learning aim D1, deliver a presentation to show a variety of easy-to-use free software packages available on the web. Demonstrate the use of one of these to the class and engage learners through a Q&A session.
- Ask learners to form into small groups to complete a research activity, where they must find some suitable software relevant to the calculations that they have carried out so far. Ask each group to use the solutions to any of their questions, such as those relating to calculation of reactions, as test data. Each group then should discuss their findings with their peers, and you should facilitate a discussion where they can give developmental and constructive feedback.

Learning aim D2

- For the delivery of learning aim D2, ask learners to carry out research into the benefits and drawbacks of computer software. Give learners a checklist of what to include in their responses. Some topical issues could be allocated to specific groups, e.g. cyber security. Have learners present their findings to the rest of the class.
- Invite a guest speaker from a design background to highlight the benefits and limitations of computer software. Support learners before the visit in order to prepare valid questions to ask the guest speaker. Follow this by facilitating a class discussion to summarise the learning during the session.
- Organise visits to a relevant exhibition, where learners can see the software in action and may have the opportunity to experience state-of-the art technology. If this could be arranged, this visit could become part of the assessment for this learning aim, where learners could complete (with the help of their visit notes) an evaluation of the chosen software.
- Learners could prepare checklists based on the unit content, so that they can record, and make note of, the relevant details.



Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- Unit 3: Construction Science
- Unit 6: Construction Mathematics
- Unit 17: Further Mathematics for Construction.

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC International Level 3 Qualifications in Civil Engineering. Check the Pearson website (<http://qualifications.pearson.com/endorsed-resources>) for more information as titles achieve endorsement.

Textbooks

Durka, F et al – *Structural Mechanics: Loads, Analysis, Materials and Design of Structural Elements*, 7th edition (Prentice Hall, 2010) ISBN 9780132239646. This is a popular text covering a range of important concepts in structural mechanics.

Raju, N – *Structural Design and Drawing: Reinforced Concrete and Steel* (Universities Press 2005) ISBN 9788173714894. Text covering columns, beams and retaining walls.

Seward, D – *Understanding Structures: Analysis, Materials, Design*, 5th edition (Palgrave, 2014) ISBN 9781137376565. This is a popular text where structural concepts are explained in a fun way.

Journals

New Civil Engineer (EMAP Publishing) – this is an Institution of Civil Engineers (ICE) journal, containing useful research and industry reports relevant to all aspects of civil engineering.

The Structural Engineer (Institution of Structural Engineers) – this is an IStructE journal which covers a broad range of areas relating to structural engineering.

Videos

Access YouTube and search for the following videos:

- 'How to Design a Retaining Wall' by Allan Block – this video explains the design of a retaining wall.
- 'Solving Beam Reactions: Multiple Point Loads' by John Tingerthal – this video shows how to determine beam reactions.
- 'Theory of Columns-1.mpg' by Arnab Dutta – this video can help learners understand the theory of columns.



Websites

Visit The Institute of Civil Engineers website – this is the professional body for civil engineers. The website contains information about the codes, products and industry updates.

Visit The Institution of Structural Engineers (IStructE) website. IStructE is the professional body for structural engineers, covering information across all aspects of structural engineering.

Visit the SkyCiv online beam calculation website for reaction forces, bending moment and shear force diagrams.

Visit The Structural Engineer: The International Information Center for Structural Engineering website, which gives an extensive list of software packages used in structural engineering.

Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors bookmark useful websites and consider enabling learners to access them through the school/college intranet.