

## National Unit Specification: general information

**UNIT** Structural Design and Detailing (Higher)

**NUMBER** D22V 12

**COURSE** Structural Engineering (Higher)

### SUMMARY

The unit seeks to develop knowledge of structural analysis and design and the application of such knowledge to the design and detailing of structural elements in steel and reinforced concrete.

The unit has been developed so that candidates may acquire the ability to design and detail structural elements in structural steelwork and in reinforced concrete to the relevant British Standards.

The unit is one of a group of units which is relevant to employment as a Structural Engineering technician.

### OUTCOMES

1. Design and detail single span, simply supported, singly reinforced concrete, slabs and rectangular beams.
2. Design and detail short, braced, axially loaded, square, reinforced concrete columns.
3. Design single span, simply supported, structural steel beams, with fully restrained compression flanges.
4. Design single storey, axially loaded, structural steel stanchions.
5. Use computer packages to illustrate the design of structural elements in reinforced concrete and structural steelwork.

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### Administrative Information

**Superclass:** TM

**Publication date:** December 1999

**Source:** Scottish Qualifications Authority 1999

**Version:** 01

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### **RECOMMENDED ENTRY**

While entry is at the discretion of the centre, candidates would normally be expected to have successfully completed, or be undertaking contemporaneously:

- Civil Engineering Technology (Higher)
- Civil Engineering Practice(Higher)
- Structural Mechanics and Design 1(Higher)
- Structural Drawing and Detailing (Higher)

### **CREDIT VALUE**

1 Credit at Higher

### **CORE SKILLS**

Information on the automatic certification of any core skills in this unit is published in *Automatic Certification of Core Skills in National Qualifications* (SQA, 1999).

## National Unit Specification: statement of standards

### UNIT Structural Design and Detailing (Higher)

Acceptable performance in this unit will be the satisfactory achievement of the standards set out in this part of the unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to the Scottish Qualifications Authority.

#### OUTCOME 1

Design and detail single span, simply supported, singly reinforced concrete, slabs and rectangular beams.

#### Performance criteria

- a) The principles of limit state design are applied, in accordance with current British Standard Code of Practice.
- b) Design shear forces and bending moments are correctly evaluated for a specified loading condition, in a given design situation.
- c) The sectional areas of concrete, and the main and secondary reinforcement are correctly determined for one way spanning, solid slabs, using design formulae and appropriate design charts.
- d) The sectional areas of concrete, main bending and vertical shear reinforcement, are correctly determined for singly reinforced rectangular beams, using design formulae and appropriate design charts.
- e) The simplified methods in PP7312 for calculating curtailment lengths of reinforcing bars in slabs and beams are applied correctly to previously designed elements.
- f) Sketch detail drawings of slabs and beams, previously designed, are produced in accordance with current practice.

#### Note on range for the Outcome

Loading conditions: uniformly distributed; concentrated; combination of both.

Design conditions (slabs and beams): bending; deflection; shear; fire resistance; exposure; cracking; concrete placement.

#### Evidence requirements

Please refer to *Evidence requirements for the unit* at the end of the Statement of Standards.

## National Unit Specification: statement of standards (cont)

**UNIT**            Structural Design and Detailing (Higher)

### **OUTCOME 2**

Design and detail short, braced, axially loaded, square, reinforced concrete columns.

#### **Performance criteria**

- a) Design loads on columns are evaluated accurately, for symmetrical loading conditions.
- b) The criteria for designating a column as short and braced are applied correctly.
- c) The sectional area of concrete, longitudinal and transverse reinforcement in columns are correctly determined, using design formulae and appropriate design charts.
- d) The main reasons for lap lengths and anchorage lengths are understood correctly.
- e) Sketch detail drawings, of two storey columns, previously designed, are produced in accordance with current practice.

#### **Evidence requirements**

Please refer to *Evidence requirements for the unit* at the end of the Statement of Standards.

### **OUTCOME 3**

Design single span, simply supported, structural steel beams, with fully restrained compression flanges

#### **Performance criteria**

- a) The design shear forces and bending moments are correctly evaluated for a specified loading condition in a given, single span, design situation.
- b) Suitable universal beam sections are chosen or checked, using flow charts, design formulae and safe load tables, for beams with compression flanges fully restrained against lateral buckling.

#### **Note on range for the Outcome**

Loading conditions: uniformly distributed; concentrated; combination of both.

Design considerations: bending; shear; local buckling; web buckling and crushing (safe load tables only); deflection.

#### **Evidence requirements**

Please refer to *Evidence requirements for the unit* at the end of the Statement of Standards.

## National Unit Specification: statement of standards (cont)

**UNIT**            Structural Design and Detailing (Higher)

### **Outcome 4**

Design single storey, axially loaded, structural steel stanchions.

#### **Performance criteria**

- a) Design loads on stanchions are evaluated accurately, for symmetrical loading conditions.
- b) The effective lengths about both axes are evaluated correctly, from given end conditions.
- c) Suitable sections are chosen or checked from design formulae and appropriate safe load tables.

#### **Note on range for the Outcome**

Steel stanchion sections: universal columns; universal beams; hollow rectangular sections.

#### **Evidence requirements**

Please refer to *Evidence requirements for the unit* at the end of the Statement of Standards

### **OUTCOME 5**

Use computer packages to illustrate the design of structural elements in reinforced concrete and structural steelwork.

#### **Performance criteria**

- a) The design of a reinforced concrete slab, rectangular beam and axially loaded square column is accurately carried out using appropriate computer software.
- b) The design of a structural steelwork beam and axially loaded stanchion is accurately carried out using appropriate computer software.
- c) The design results obtained by computer software are correctly compared with those from manual calculations.

#### **Evidence requirements**

Please refer to *Evidence requirements for the unit* at the end of the Statement of Standards

## National Unit Specification: statement of standards (cont)

**UNIT**            Structural Design and Detailing (Higher)

### EVIDENCE REQUIREMENTS FOR THE UNIT

#### Outcome 1

Oral or written evidence indicating a knowledge and understanding of the following is required from the candidate:

- i)        the principles of limit state design;  
This may be evidenced by the candidate interpreting and applying the relevant clauses of PP 7312 throughout the appropriate performance criteria of the Outcome.
- ii)       the evaluation of design bending moments and shear forces;  
This may be evidenced by the candidate evaluating the characteristic and design loads on a particular structural elements and hence evaluating the critical design shear force and bending moment at required points on the structural element.
- iii)      the design of slabs;  
This may be evidenced by the candidate determining a suitable slab thickness or checking a given slab thickness, considering bending, deflection, exposure conditions, fire resistance and shear. The candidate would then evaluate the amount of main and secondary reinforcement required, considering bending, cracking, and concrete placement, the reinforcement being found from design formulae and appropriate design charts.
- iv)      the design of beams;  
This may be evidenced by the candidate determining a suitable beam depth or checking a given beam depth, considering bending, deflection, shear, fire resistance and exposure conditions. The candidate would then evaluate the amount of main and vertical link shear reinforcement, considering bending, cracking, concrete placement and shear, as required, the main reinforcement being found from design formulae and appropriate design charts.
- v)        the principles of reinforcement detailing;  
This may be evidenced by the candidate applying the relevant clauses of PP 7312 and the appropriate sections of "Standard Methods of Detailing Structural Concrete" to examples of a previously designed slab and beam, in order to produce sketch detail drawings.

'Open book' assessment should be used for this outcome.

#### Outcome 2

Oral or written evidenced indicating a knowledge and understanding of the following is required from the candidate:

- i)        the principles of limit state design;  
This may be evidenced by the candidate interpreting and applying the relevant clauses of PP 7312 throughout the appropriate performance criteria of the Outcome.
- ii)       the loading analysis of columns;  
This may be evidenced by the candidate evaluating the characteristic and design loading on a column.
- iii)      the design of columns;  
This may be evidenced by the candidate calculating a suitable concrete size, or checking a given concrete size for a short, braced, square column for a given design situation, and hence evaluating the main and transverse reinforcement required, using design formulae and appropriate design charts.

## National Unit Specification: statement of standards (cont)

**UNIT**            Structural Design and Detailing (Higher)

- iv)        the principles of reinforcement detailing;  
This may be evidenced by the candidate applying the relevant clauses of PP 7312 and the appropriate sections of “Standard Methods of Detailing Structural Concrete” to examples of a previously designed column, in order to produce sketch detail drawings, from top of foundation pad to top of supported beams.

‘Open book’ assessment should be used for this outcome.

### **Outcome 3**

Oral or written evidence indicating a knowledge and understanding of the following is required from the candidate:

- i)        the principles of limit state design;  
This may be evidenced by the candidate interpreting and applying the relevant clauses of PP 7312 throughout the appropriate performance criteria of the Outcome.
- ii)       the evaluation of design bending moments and shear forces;  
This may be evidenced by the candidate evaluating the characteristic and design loads on a particular steel beam and hence evaluating the critical design shear force and bending moment at required points on the beam.
- iii)      the design of beams;  
This may be evidenced by the candidate checking a given beam section for bending, shear, deflection and web buckling and crushing, using flow charts, design formulae, and section property tables and checking, where possible from relevant safe load tables.

‘Open book’ assessment should be used for this outcome.

### **Outcome 4**

Oral or written evidence indicating a knowledge and understanding of the following is required from the candidate:

- i)        the principles of limit state design;  
This may be evidenced by the candidate interpreting and applying the relevant clauses of PP 7312 throughout the appropriate performance criteria of the Outcome.
- ii)       the design of single storey stanchions;  
This may be evidenced by the candidate being given the proposed section and checking its suitability under axial loading. Cases where the design formulae and cases where the appropriate safe load tables are used should be considered.

‘Open book’ assessment should be used for this outcome.

## **National Unit Specification: statement of standards (cont)**

**UNIT**            Structural Design and Detailing (Higher)

### **Outcome 5**

Oral or written evidence indicating a knowledge and understanding of the following is required from the candidate:

- i)        the use of computer packages to solve structural design problems;  
          This may be evidenced by the candidate applying commercial or “in house” computer packages to solve structural design problems met in previous outcomes viz: reinforced concrete slab, beam and column and steelwork beam and stanchion. A representative selection of the results obtained from the computer packages should be compared with those obtained from manual calculations.

‘Open book’ assessment should be used for this outcome.

## National Unit Specification: support notes

### UNIT Structural Design and Detailing (Higher)

This part of the unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this unit is at the discretion of the centre, the notional design length is 40 hours.

#### **GUIDANCE ON THE CONTENT AND CONTEXT FOR THIS UNIT**

The unit develops the candidate's knowledge and understanding of designing reinforced concrete and steelwork structural elements to the current British Standards. The skills in the detailing of reinforced concrete elements, previously introduced, are now extended to allow the candidate to use their design results in the detail drawings produced.

The candidate's knowledge of stress analysis will be extended to the theory of limit state design, and its application to reinforced concrete and steelwork design.

Corresponding to outcomes 1 to 5:

- 1 This outcome should provide candidates with a knowledge and understanding of limit state design, its terminology and its main differences from permissible stress design. The candidates should then have the knowledge and ability to apply the principles to both reinforced concrete and steelwork. The principles will then be developed to provide candidates with the ability to design and detail reinforced concrete elements viz: simply supported slabs and singly reinforced rectangular beams. The candidates will also be provided with the knowledge and ability to assess the correct loading on a slab or beam, for analysis purposes, from a given general arrangement drawing.

Information sources: relevant clauses from PP7312; relevant design charts from BS8110; relevant sections from Standard Method of Detailing Structural Concrete.

Materials: grade 40 concrete; main reinforcement  $f_y = 460 \text{ N/mm}^2$ ; shear reinforcement  $f_{yv} = 250 \text{ N/mm}^2$ .

- 2 This outcome should provide candidates with the ability to assess that a reinforced concrete column is short and braced and hence to design the column under an axial load which the candidate will have been able to assess. The candidates will also be provided with the ability to detail the column, designed previously.

Information sources; relevant clauses from PP7312; relevant design charts from BS8110. Materials: grade 40 concrete; main reinforcement  $f_y = 460 \text{ N/mm}^2$ .

- 3 This outcome should provide candidates with the knowledge and ability to apply limit state design to steel beams with their compression flange fully restrained against lateral buckling. Candidates will also be introduced to safe load tables as an aid to design.

Information sources: relevant clauses from PP7312; relevant tables and flowcharts from Steel Construction Institute.

## National Unit Specification: support notes (cont)

### UNIT            Structural Design and Detailing (Higher)

- 4            This outcome should extend the understanding of the candidates to the checking of axially loaded steel stanchions.

Information sources: relevant clauses from PP7312; relevant tables from Steel Construction Institute.

- 5            This outcome should provide candidates with the ability to use relevant computer packages to carry out the design of elements met in earlier outcomes.

### GUIDANCE ON LEARNING AND TEACHING APPROACHES FOR THIS UNIT

Since this a very practical unit, every opportunity should be taken to introduce the candidate to examples of design aids used in practice e.g. safe load tables for steelwork, designs charts for reinforced concrete, I. Struct.E. Handbooks in reinforced concrete and steelwork etc. Use should also be made of consultant engineers' detail drawings and relevant videos of design/construction interaction.

### GUIDANCE ON APPROACHES TO ASSESSMENT FOR THIS UNIT

Centres may use the instruments of assessment which they consider to be the most appropriate.

Examples of instruments which could be used are as follows:

#### Outcome 1

- a)            A one way spanning slab, consisting of one span with supporting rectangular (precast) beams, could be given. The thickness of slab and the characteristic and design loading on slab and beams are calculated and the slab and beam designed. The given range of loading conditions should be covered.
- b)            The designed slab is detailed in plan and section and a beam is detailed in elevation and section.

Satisfactory achievement of this outcome will be based on the candidate meeting sufficient criteria established for a competent practical solution.

#### Outcome 2

- a)            The part plan of the floor and roof in which a square column of given dimensions supports a symmetrical beam arrangement, is given. The characteristic and design loads on the lower storey of the column are calculated and the main and transverse reinforcement designed, checking that the column is "short".
- b)            Assuming that the reinforcement in the upper storey is similar to that designed for the lower storey but that a splice is required above floor level, the designed column is detailed in elevation and section from top of base pad to top of roof beam, with main column detailed to avoid given floor and roof beam reinforcement.

## National Unit Specification: support notes (cont)

### UNIT Structural Design and Detailing (Higher)

Satisfactory achievement of this outcome will be based on the candidate meeting sufficient criteria established for a competent practical solution.

#### Outcome 3

The candidate could be set two structured questions on steel beams. Both questions could require the candidate to calculate the characteristic and design loads on a beam shown in a given floor plan. The given range of loading conditions should be covered. In both cases the compression flange of the beams should be assumed to be fully restrained.

Both beams should be fully checked, one beam using code formulae while in the other, appropriate safe load tables should be used.

Satisfactory achievement of this outcome will be based on the candidate meeting sufficient criteria established for a competent practical solution.

#### Outcome 4

Three examples on axially loaded steel stanchions could be given as follows:

- a) The characteristic and design loads on a symmetrically loaded stanchion are evaluated and a given universal column section with equal effective heights about both axes is checked, using code clauses.
- b) For a different loading condition, a universal beam section, with differing effective heights about each axis is checked, using code clauses.
- c) From safe load tables a suitable rectangular hollow section is chosen as an alternative in a and b.

Satisfactory achievement of this outcomes will be based on the candidate producing, as a minimum, a correct answer to a or b plus a correct answer to c.

#### Outcome 5

Using appropriate software, the candidate could produce design printouts for the following:

- a) Reinforced concrete slab of outcome 1.
- b) Reinforced concrete beam of outcome 1
- c) Reinforced concrete column of outcome 2
- d) One steel beam of outcome 3
- e) One steel stanchion of outcome 4.

Satisfactory achievement of this outcome will be based on the candidate producing, as a minimum, acceptable printouts to two reinforced concrete elements plus one steel element, provided a comparison is made with the appropriate manual calculation and any differences explained in any two of the above examples.

## National Unit Specification: support notes (cont)

**UNIT**            Structural Design and Detailing (Higher)

### **SPECIAL NEEDS**

This unit specification is intended to ensure that there are no artificial barriers to learning or assessment. Special needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments or considering special alternative outcomes for units. For information on these, please refer to the SQA document *Guidance on Special Assessment and Certification Arrangements for Candidates with Special Needs/Candidates whose First Language is not English* (SQA, 1998).