Chapter 1

1. d

2. a

3. d

4. d

5. c

6. b

7. c

8. In elastic-plastic model (Figure 1.4c), the stress-strain plot consists of two separate segments with the first segment being perfectly elastic and the second being perfectly plastic. In elasto-plastic model, the elastic and plastic strains occur simultaneously at all strain levels.

9. $\sigma = \dfrac{\varepsilon}{a + b\varepsilon}$

   This can be written as

   $\sigma = \dfrac{1}{a/\varepsilon + b}$

   When ε ➔ ∞, σ = σ_u = **1/b**

   $\dfrac{d\sigma}{d\varepsilon} = \dfrac{(a+b\varepsilon)1 - b\varepsilon}{(a+b\varepsilon)^2} = \dfrac{a}{(a+b\varepsilon)^2}$

   At ε = 0, $\dfrac{d\sigma}{d\varepsilon} = \dfrac{1}{a}$

10. From Figure 1.16, the yield stress is about 145 MPa.
    Young's modulus E = 155/0.005 = 31,000 MPa or 31.0 GPa.

    At 3% strain (i.e., ε = 0.03), the stress is 280 MPa.

    Unloading takes place along the line BC shown in the figure. The elastic strain is given by

    $\varepsilon^e = \dfrac{280}{31000} = 0.009$ or 0.9%

    Therefore, the plastic strain is given by

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$$\varepsilon^p = \varepsilon - \varepsilon^e = 0.03 - 0.009 = 0.021 \text{ or } 2.1\%$$

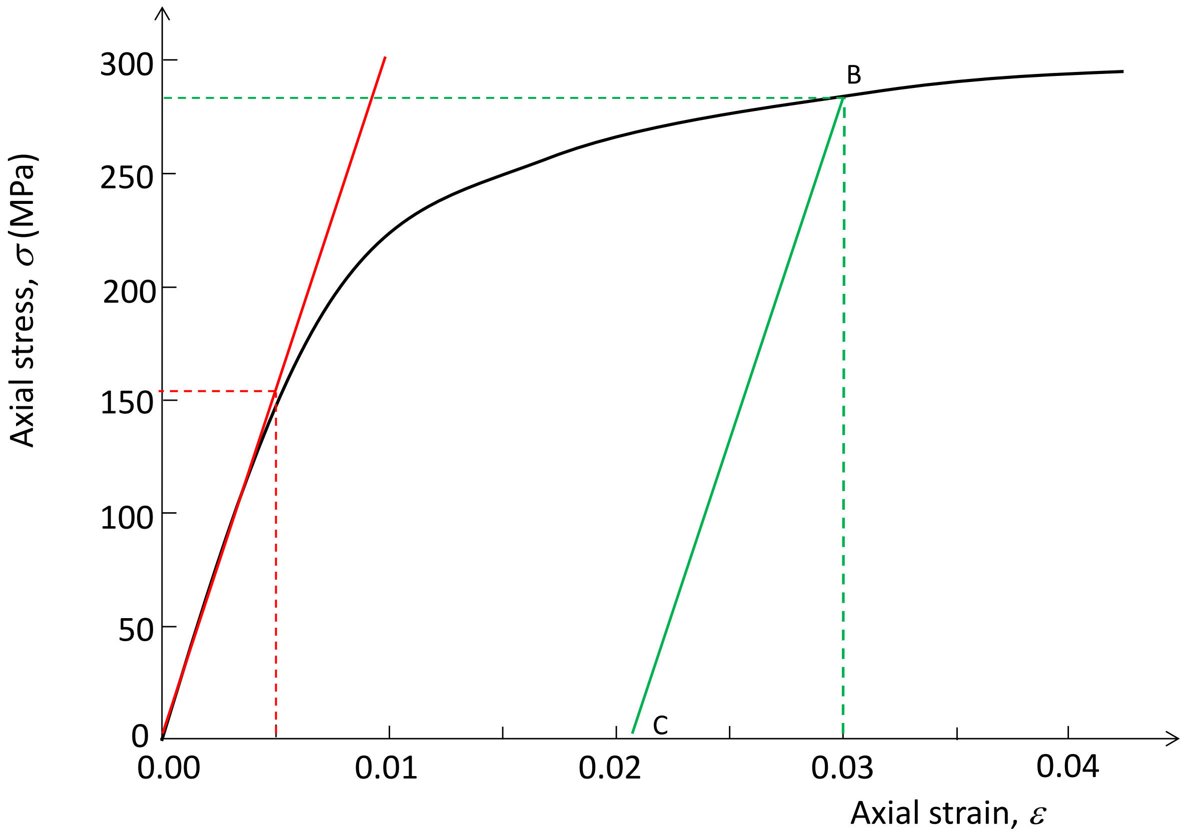
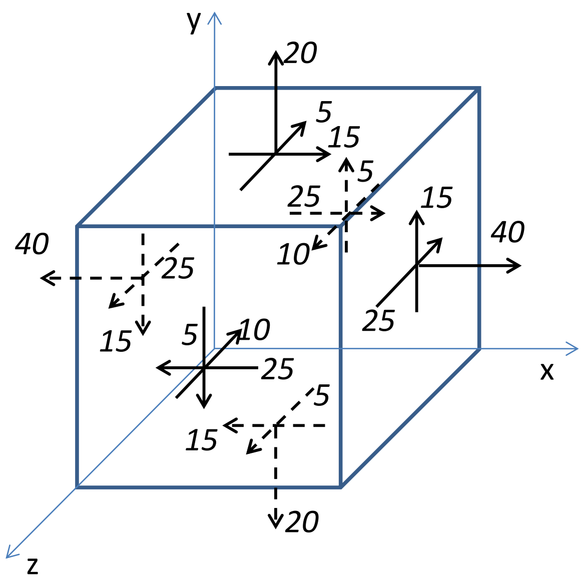


Figure 1.16

11. The element is shown in the figure here.



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12.

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{Bmatrix} = \frac{1}{E} \begin{bmatrix} 1 & -\nu & -\nu & 0 & 0 & 0 \\ -\nu & 1 & -\nu & 0 & 0 & 0 \\ -\nu & -\nu & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2(1+\nu) & 0 & 0 \\ 0 & 0 & 0 & 0 & 2(1+\nu) & 0 \\ 0 & 0 & 0 & 0 & 0 & 2(1+\nu) \end{bmatrix} \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix} \qquad (1.15)$$

For principal stresses (and no shear stresses),

$$\begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{Bmatrix} = \frac{1}{E} \begin{bmatrix} 1 & -\nu & -\nu & 0 & 0 & 0 \\ -\nu & 1 & -\nu & 0 & 0 & 0 \\ -\nu & -\nu & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2(1+\nu) & 0 & 0 \\ 0 & 0 & 0 & 0 & 2(1+\nu) & 0 \\ 0 & 0 & 0 & 0 & 0 & 2(1+\nu) \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ 0 \\ 0 \\ 0 \end{Bmatrix}$$

This can be simplified as

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{pmatrix} = \frac{1}{E} \begin{pmatrix} 1 & -\nu & -\nu \\ -\nu & 1 & -\nu \\ -\nu & -\nu & 1 \end{pmatrix} \begin{pmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{pmatrix}$$

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix} = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & \nu & 0 & 0 & 0 \\ \nu & 1-\nu & \nu & 0 & 0 & 0 \\ \nu & \nu & 1-\nu & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{(1-2\nu)}{2} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{(1-2\nu)}{2} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{(1-2\nu)}{2} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{Bmatrix} \qquad (1.16)$$

For principal strains (and no shear strains),

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix} = \frac{E}{(1+\nu)(1-2\nu)} \begin{bmatrix} 1-\nu & \nu & \nu & 0 & 0 & 0 \\ \nu & 1-\nu & \nu & 0 & 0 & 0 \\ \nu & \nu & 1-\nu & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{(1-2\nu)}{2} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{(1-2\nu)}{2} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{(1-2\nu)}{2} \end{bmatrix} \begin{Bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ 0 \\ 0 \\ 0 \end{Bmatrix}$$

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$$\begin{pmatrix}\sigma_1\\ \sigma_2\\ \sigma_3\end{pmatrix} = \frac{E}{(1+\nu)(1-2\nu)}\begin{pmatrix}1-\nu & \nu & \nu\\ \nu & 1-\nu & \nu\\ \nu & \nu & 1-\nu\end{pmatrix}\begin{pmatrix}\varepsilon_1\\ \varepsilon_2\\ \varepsilon_3\end{pmatrix}$$

13. Some of the systems of units include:
    - SI
    - English
    - US Customary Units (derived from English units)
    - MKS (meter, kilogram and second) system of units
    - Metric

    See https://en.wikipedia.org and other sites for details.

    Some of the advantages of SI units are as follows.

    - Only one unit for each physical quantity.
    - No fractions and only decimals.
    - Short and unambiguous prefixes.
    - Power of 10. Nothing to memorise (e.g. mile = 5280 ft).
    - World-wide use

14. Non-destructive testing

Often we take samples from steel, concrete, timber, soils and rocks for testing in the laboratory. Sometimes, it is required to test the structure without causing even the slightest damage. That is, we cannot always obtained specimens from the structure for testing. Such non-destructive testing methods apply to all branches of civil engineering. Look for the following points for the 500-word essay.

- Acoustic emission
- Hardness testing
- Optical or scanning electron microscopy
- NDT applications in concrete, steel, timber, rocks and soils
- Schmidt rebound hammer
- Digital imaging
- Electromagnetic methods
- Leak testing
- Nuclear density meter
- Geophysical methods
- Structural health monitoring

15. *Impact echo tester* is used for measuring thicknesses of concrete elements and detect cracks, honeycombing or other damages in concrete.
    Half-cell potential meter (ASTM C876) is used for measuring the surface potential differences induced by any corrosion process and hence any likelihood of future corrosion in the reinforcements.

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Acoustic emission is a technique where elastic waves are sent through the material to detect the properties.
Scanning electron microscope is used to obtained images of the microstructure of most materials.

16. Look for ABAQUS, ANSYS, ELFEN, RocScience, Plaxis, FLAC, UDEC, Matlab, ETABS, STAAD Pro, SAP2000, etc.

17.

a. Angstrom = 10^{-10} m
b. kip = 4.448×10^{3} N
c. psi = 6.895×10^{3} Pa
d. bar = 10^{5} Pa

18.

a. 3
b. 2
c. 5
d. 5
e. 3

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