

CIVIL ENGINEERING

ESE TOPICWISE
CONVENTIONAL SOLVED PAPER-I

1995-2021



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PREFACE

Engineering Services Exam (ESE) is one of most coveted exams written by engineering students aspiring for reputed posts in the various departments of the Government of India. ESE is conducted by the Union Public Services Commission (UPSC), and therefore the standards to clear this exam too are very high. To clear the ESE, a candidate needs to clear three stages – ESE Prelims, ESE Mains and Personality Test.

It is not mere hard work that helps a student succeed in an examination like ESE that witnesses lakhs of aspirants competing neck to neck to move one step closer to their dream job. It is hard work along with smart work that allows an ESE aspirant to fulfil his dream.

After detailed interaction with students preparing for ESE, IES Master has come up with this book which is a one-stop solution for engineering students aspiring to crack this most prestigious engineering exam. The book includes previous years' solved conventional questions segregated subject-wise along with detailed explanation. This book will also help ESE aspirants get an idea about the pattern and weightage of questions asked in ESE.

IES Master feels immense pride in bringing out this book with utmost care to build upon the exam preparedness of a student up to the UPSC standards. The credit for flawless preparation of this book goes to the entire team of IES Master Publication. Teachers, students, and professional engineers are welcome to share their suggestions to make this book more valuable.

MR. KANCHAN KUMAR THAKUR
DIRECTOR—IES MASTER

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CHAPTER 1

STRENGTH OF MATERIALS

Q-1: A cylindrical piece of steel 80 mm dia and 120 mm long is subjected to an axial compressive force of 50,000 kg. Calculate the change in the volume of the piece if bulk modulus = 1.7×10^6 kg/cm² and Poisons' ratio = 0.3.

[10 Marks, ESE-1997]

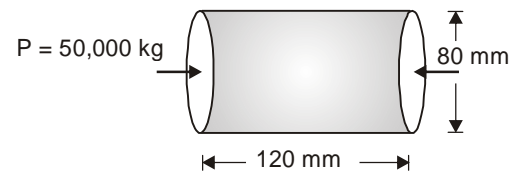
Sol: **Given:**

Axial compressive load = 50,000 kg

Bulk modulus (k) = 1.7×10^6 kg/cm²

Passion's ratio (μ) = 0.3

Determine:



We know that

$$\frac{\Delta V}{V} = \varepsilon_v = \varepsilon_x + \varepsilon_y + \varepsilon_z$$

$$\varepsilon_x = \frac{\sigma_x}{E} - \frac{\mu(\sigma_y)}{E} - \frac{\mu(\sigma_z)}{E}$$

$$\varepsilon_y = \frac{\sigma_y}{E} - \frac{\mu(\sigma_z)}{E} - \frac{\mu(\sigma_x)}{E}$$

$$\varepsilon_z = \frac{\sigma_z}{E} - \frac{\mu(\sigma_x)}{E} - \frac{\mu\sigma_y}{E}$$

In our case,

$$\sigma_y = 0 ; \sigma_z = 0$$

$$\sigma_x = \frac{-50000 \text{ kg}}{\frac{\pi}{4} (8)^2 \text{ cm}^2} = -995.2 \text{ kg/cm}^2 \quad \{(-ve) \text{ because its compressive}\}$$

Also, we know,

$$E = 3k(1-2\mu) = 3 \times 1.7 \times 10^6 \times (1 - 2 \times 0.3) \\ = 2.04 \times 10^6 \text{ kg/cm}^2$$

$$\Rightarrow \varepsilon_x = \frac{\sigma_x}{E} = \frac{-995.2}{2.04 \times 10^6} = -4.8784 \times 10^{-4} \quad [(-) \text{ because comp.}]$$

$$\varepsilon_y = -\frac{\mu\sigma_x}{E} = 0.3 \times 4.878 \times 10^{-4} = 1.4635 \times 10^{-4}$$

$$\varepsilon_z = -\frac{\mu\sigma_x}{E} = 1.4635 \times 10^{-4}$$

$$\Rightarrow \varepsilon_v = \varepsilon_x + \varepsilon_y + \varepsilon_z = -1.951 \times 10^{-4}$$

$$\Rightarrow \frac{\Delta V}{V} = -1.951 \times 10^{-4}$$

$$\Delta V = -1.951 \times 10^{-4} \times \frac{\pi}{4} (8)^2 \times 12 \text{ cm}^3 = -0.1176 \text{ cm}^3$$

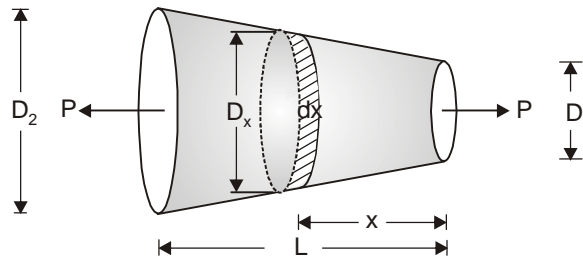
Change in vol. is (-)ve

\Rightarrow There is volume reduction of 0.1176 cm^3

Q-2: A steel rod, circular in cross-section, tapers from 30 mm diameter to 15 mm diameter over a length of 600 mm. Find how much its length will increase under a pull of 20 kN if Young's modulus of elasticity = 200 kN/mm². Derive the formula used.

[15 Marks, ESE-1998]

Sol:



For deriving the expression of elongation for tapered beam, we assume a tapered beam of Length = L, Small end Dia = D_1 , Larger end dia = D_2

$$\therefore D_x = D_1 + \left(\frac{D_2 - D_1}{L} \right) x, \quad \{\text{where } D_x \text{ is Dia at any distance } x \text{ from smaller end}\}$$

$$\text{i.e., } D_x = D_1 + kx, \quad \text{where } k = \left(\frac{D_2 - D_1}{L} \right)$$

Change in the length of element of length $dx = d(\Delta L)$

$$d(\Delta L) = \frac{P dx}{AE}$$

$$\text{So net elongation} \quad \int d(\Delta L) = \int_0^L \frac{P dx}{AE} = \int_0^L \frac{P dx}{\frac{\pi}{4} (D_1 + kx)^2 E}$$

$$\Rightarrow \Delta L = \int_0^L \frac{4P dx}{\pi (D_1 + kx)^2 E} = \frac{4P}{\pi E} \int_0^L \frac{dx}{(D_1 + kx)^2} = \frac{4P}{\pi E} \left[\frac{-1}{k(D_1 + kx)} \right]_0^L$$

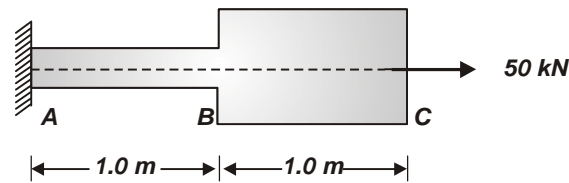
$$\Rightarrow \boxed{\Delta L = \frac{4PL}{\pi E D_1 D_2}}$$

Values given, $P = 20 \text{ kN} = 20 \times 10^3 \text{ N}$

$D_1 = 15 \text{ mm}$, $D_2 = 30 \text{ mm}$, $L = 600 \text{ mm}$, $E = 200 \text{ kN/mm}^2 = 200 \times 10^3 \text{ N/mm}^2$

$$\therefore \Delta L = \frac{4 \times 20 \times 10^3 \times 600}{\pi \times 15 \times 30 \times 200 \times 10^3} = 0.1697 \text{ mm}$$

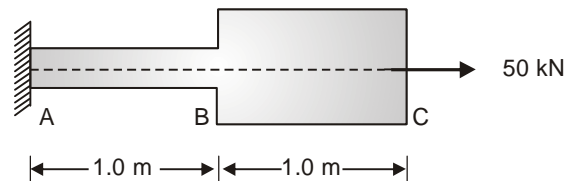
- Q-3: Draw the diagram of normal forces, stresses and displacements along the length of the stepped bar ABC shown in figure.



cross-sectional area over AB = 100 mm^2 ; and area over BC = 200 mm^2 ; modulus of elasticity = 200 kN/mm^2

[10 Marks, ESE-1998]

Sol:



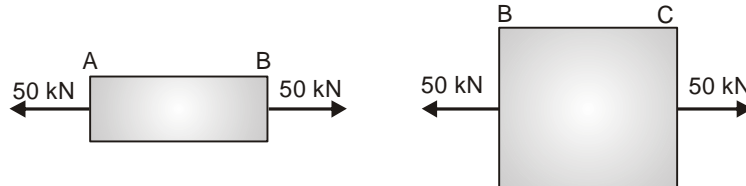
Given:

$$A_{AB} = 100 \text{ mm}^2, \quad A_{BC} = 200 \text{ mm}^2, \quad E = 200 \text{ kN/mm}^2$$

Draw

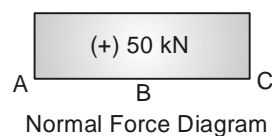
Diagram of normal forces normal stresses & displacement \rightarrow along the length

- FBD for AB and BC,



- Normal force diagram

Normal force diagram will be constant equal to 50 kN (tension)



- Normal stress diagram

$$\text{Stress, } \sigma_{AB} = \left(\frac{50 \times 1000}{100} \right) = 500 \text{ N/mm}^2$$

$$\sigma_{BC} = \frac{50 \times 1000}{200} = 250 \text{ N/mm}^2$$

The normal stress diagram have discontinuity at interface as shown below

