CIVIL ENGINEERING

ESE TOPICWISE

CONVENTIONAL SOLVED PAPER-I

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Office: F-126, (Lower Basement), Katwaria Sarai, New Delhi-110 016

Phone: 011-2652 2064 ▪ **Mobile:** 81309 09220, 97118 53908

Email: info.publications@iesmaster.org, info@iesmaster.org

Web: iesmasterpublications.com, iesmaster.org

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F-126, (Lower Basement), Katwaria Sarai, New Delhi-110016

Phone : 011-26522064, **Mobile :** 8130909220, 9711853908

E-mail : info.publications@iesmaster.org

Web : iesmasterpublications.com

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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

CONTENT

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/cm^2 and Poisons' ratio = 0.3.***

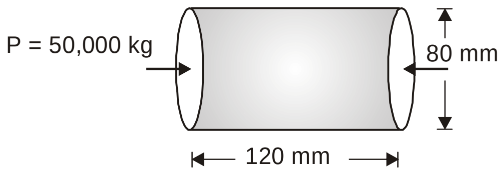
[10 Marks, ESE-1997]

Sol: **Given:**

Axial compressive load = 50,000 kg

Bulk modulus (k) = $1.7 \times 10^{+6}$ kg/cm^2

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

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

Also, we know, $$E = 3k(1-2\mu) = 3 \times 1.7 \times 10^6 \times (1 - 2\times 0.3)$$

$$= 2.04 \times 10^6 \text{ kg/cm}^2$$

$\Rightarrow$ $$\varepsilon_x = \frac{\sigma_x}{E} = \frac{-995.2}{2.04 \times 10^6} = -4.878\,4 \times 10^{-4}$$ [(–) because comp.]

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

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

$\Rightarrow$ $$\varepsilon_v = \varepsilon_x + \varepsilon_y + \varepsilon_2 = -1.951 \times 10^{-4}$$

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

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

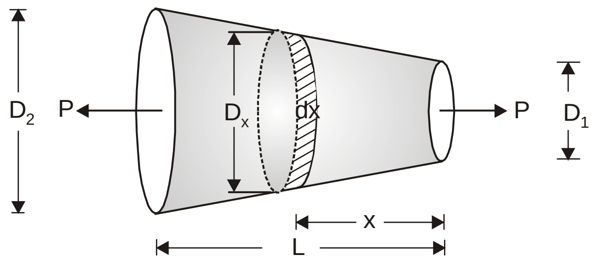
Change in vol. is (–)ve

$\Rightarrow$ 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/mm^2. 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

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

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

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

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

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

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

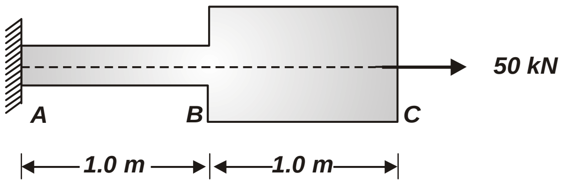
$$\Rightarrow \quad \boxed{\Delta L = \frac{4PL}{\pi E D_1 D_2}}$$

Values given, P = 20 kN = 20 × 10^3 N

D_1 = 15 mm, D_2 = 30 mm, L = 600 mm, E = 200 kN/mm^2 = 200 × 10^3 N/mm^2

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

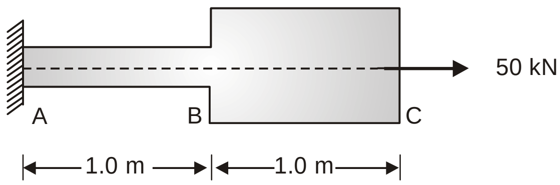
Q-3: ***Draw the diagram of normal forces, stresses and displacements along the length of the stepped bar ABC shown in figure.***



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:



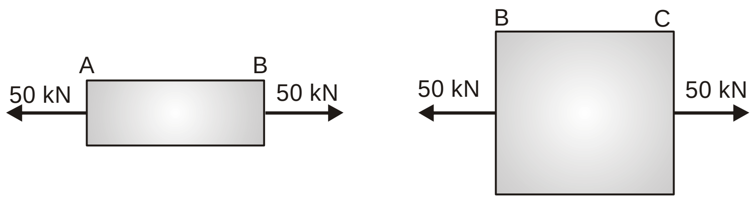
Given:

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

Draw

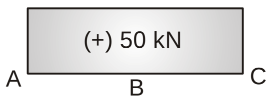
Diagram of normal forces normal stresses & displacement $\rightarrow$ along the length

- **FBD for AB and BC,**



- **Normal force diagram**

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



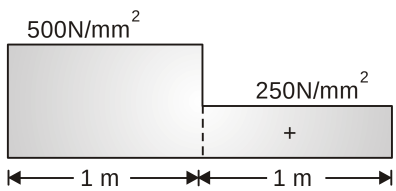
Normal Force Diagram

- **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



Normal stress Diagram

- **Displacement diagram**

We know that displacement , $\delta = \frac{PL}{AE}$ or $\frac{\sigma L}{E}$

For portion AB, σ = 500 N/mm^2 and E = 2 × 10^5 N/mm^2.

$$\therefore \quad \delta = \left(\frac{500 \times L}{2 \times 10^5}\right)\text{meter, where L is meter}$$

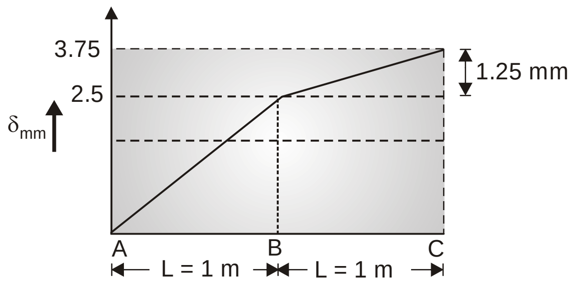
$$= \left(\frac{500 \times L \times 1000}{2 \times 10^5}\right)\text{mm, where L in meter}$$

$$\delta = (2.5\ L)\ \text{mm}$$

For portion BC, σ = 250 N/mm^2

$$\therefore \quad \delta = \left(\frac{250 \times L \times 1000}{2 \times 10^5}\right) = (1.25L)\text{mm, where L in meter}$$

So, Displacement curve is as shown below,



Q-4: ***(a)*** ***The given figure shows three metal cubes A, B and C, of side 100 mm in direct contact, resting on a rigid base and confined in the x-coordinate direction between two rigid end-plates.***

If the upper face of the centre cube (cube B) is subjected to uniform compressive stress of 0.5 kN/mm^2, compute for cube B, the following:

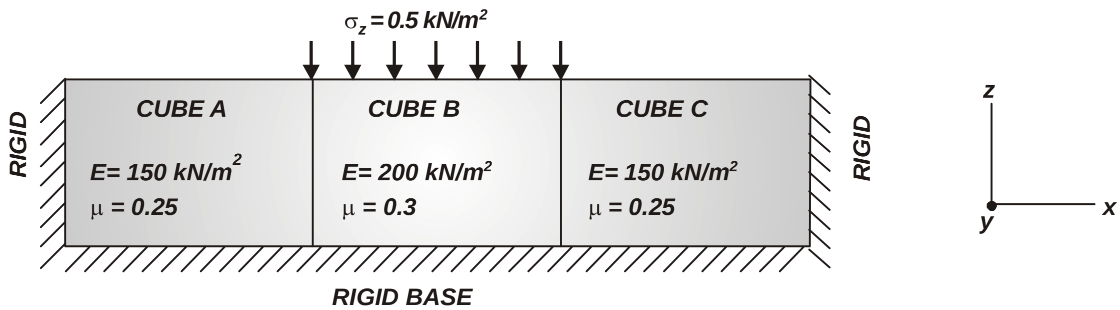
(i) ***The direct stress in the x-direction (σ_A).***

(ii) ***The direct strains in the three coordinate directions x, y and z.***

(iii) ***The volumetric strain.***

The elastic properties for the three cubes A, B and C are given in figure.

(b) ***State all assumptions made.***



[30 + 10 = 40 Marks, ESE-1999]