Important Structural Analysis of Beams Formulas PDF

Formulas
Examples
with Units

List of 26
Important Structural Analysis of Beams Formulas

1) Area to Maintain Stress as Wholly Compressive given Eccentricity Formula

Evaluate Formula

Formula

$$A = \frac{Z}{e'}$$

Example with Units

$$5600\,\text{mm}^2 = \frac{1120000\,\text{mm}^3}{200\,\text{mm}}$$

2) Beam Breadth of Uniform Strength for Simply Supported Beam when Load is at Centre Formula

Evaluate Formula

Formula

$$B = \frac{3 \cdot P \cdot a}{\sigma \cdot d_e^{\,2}}$$

Example with Units

$$96.9529\,\text{mm} = \frac{3 \cdot 0.15\,\text{kN} \cdot 21\,\text{mm}}{1200\,\text{Pa} \cdot 285\,\text{mm}^2}$$

3) Beam Depth of Uniform Strength for Simply Supported Beam when Load is at Centre Formula

Evaluate Formula

Formula

$$d_e = \sqrt{\frac{3 \cdot P \cdot a}{B \cdot \sigma}}$$

Example with Units

$$280.6239\,\text{mm} = \sqrt{\frac{3 \cdot 0.15\,\text{kN} \cdot 21\,\text{mm}}{100.0003\,\text{mm} \cdot 1200\,\text{Pa}}}$$

4) Breadth for Rectangular Section to Maintain Stress as Wholly Compressive Formula

Evaluate Formula

Formula

$$t = 6 \cdot e'$$

Example with Units

$$1200\,\text{mm} = 6 \cdot 200\,\text{mm}$$

5) Eccentricity for Rectangular Section to maintain Stress as Wholly Compressive Formula

Evaluate Formula

Formula

$$e' = \frac{t}{6}$$

Example with Units

$$200\,\text{mm} = \frac{1200\,\text{mm}}{6}$$

6) Eccentricity for Solid Circular Sector to Maintain Stress as Wholly Compressive Formula

Evaluate Formula

Formula

$$e' = \frac{\Phi}{8}$$

Example with Units

$$95\,\text{mm} = \frac{760\,\text{mm}}{8}$$

7) Eccentricity in Column for Hollow Circular Section when Stress at Extreme Fibre is Zero Formula

Evaluate Formula

Formula

$$e' = \frac{D^2 + d_i^{\,2}}{8 \cdot D}$$

Example with Units

$$1281.25\,\text{mm} = \frac{4000\,\text{mm}^2 + 5000\,\text{mm}^2}{8 \cdot 4000\,\text{mm}}$$

8) Eccentricity to Maintain Stress as Wholly Compressive Formula

Evaluate Formula

Formula

$$e' = \frac{Z}{A}$$

Example with Units

$$200\,\text{mm} = \frac{1120000\,\text{mm}^3}{5600\,\text{mm}^2}$$

9) Loading of Beam of Uniform Strength Formula

Evaluate Formula

Formula

$$P = \frac{\sigma \cdot B \cdot d_e^{\,2}}{3 \cdot a}$$

Example with Units

$$0.1547\,\text{kN} = \frac{1200\,\text{Pa} \cdot 100.0003\,\text{mm} \cdot 285\,\text{mm}^{2}}{3 \cdot 21\,\text{mm}}$$

10) Section Modulus to Maintain Stress as Wholly Compressive given Eccentricity Formula

Evaluate Formula

Formula

$$Z = e' \cdot A$$

Example with Units

$$1.1E{+}6\,\text{mm}^3 = 200\,\text{mm} \cdot 5600\,\text{mm}^2$$

11) Stress of Beam of Uniform Strength Formula

Evaluate Formula

Formula

$$\sigma = \frac{3 \cdot P \cdot a}{B \cdot d_e^{\,2}}$$

Example with Units

$$1163.4314\,\text{Pa} = \frac{3 \cdot 0.15\,\text{kN} \cdot 21\,\text{mm}}{100.0003\,\text{mm} \cdot 285\,\text{mm}^{2}}$$

12) Continuous Beams Formulas

12.1) Absolute Value of Maximum Moment in Unbraced Beam Segment Formula

Evaluate Formula

Formula

$$M'max = \frac{M_{coeff} \cdot \left(\left(3 \cdot M_A\right) + \left(4 \cdot M_B\right) + \left(3 \cdot M_C\right)\right)}{12.5 - \left(M_{coeff} \cdot 2.5\right)}$$

Example with Units

$$50.2332\,\text{N*m} = \frac{1.32\,\text{N*m} \cdot \left(\left(3 \cdot 30\,\text{N*m}\right) + \left(4 \cdot 50.02\,\text{N*m}\right) + \left(3 \cdot 20.01\,\text{N*m}\right)\right)}{12.5 - \left(1.32\,\text{N*m} \cdot 2.5\right)}$$

12.2) Condition for Maximum Moment in Interior Spans of Beams Formula

Evaluate Formula

Formula

$$x'' = \left(\frac{Len}{2}\right) - \left(\frac{M_{max}}{q \cdot Len}\right)$$

Example with Units

$$1.4997\,\text{m} = \left(\frac{3\,\text{m}}{2}\right) - \left(\frac{10.03\,\text{N*m}}{10.0006\,\text{kN/m} \cdot 3\,\text{m}}\right)$$

12.3) Condition for Maximum Moment in Interior Spans of Beams with Plastic Hinge Formula

Evaluate Formula

Formula

$$x = \left(\frac{Len}{2}\right) - \left(\frac{k \cdot M_p}{q \cdot Len}\right)$$

Example with Units

$$1.2498\,\text{m} = \left(\frac{3\,\text{m}}{2}\right) - \left(\frac{0.75 \cdot 10.007\,\text{kN*m}}{10.0006\,\text{kN/m} \cdot 3\,\text{m}}\right)$$

12.4) Ultimate Load for Continuous Beam Formula

Evaluate Formula

Formula

$$U = \frac{4 \cdot M_p \cdot \left(1 + k\right)}{Len}$$

Example with Units

$$23.3497\,\text{kN} = \frac{4 \cdot 10.007\,\text{kN*m} \cdot \left(1 + 0.75\right)}{3\,\text{m}}$$

13) Elastic Lateral Buckling of Beams Formulas

13.1) Absolute Value of Moment at Centerline of Unbraced Beam Segment Formula

Evaluate Formula

Formula

$$M_B = \frac{\left(12.5 \cdot M'max\right) - \left(2.5 \cdot M'max + 3 \cdot M_A + 3 \cdot M_C\right)}{4}$$

Example with Units

$$87.5175\,\text{N*m} = \frac{\left(12.5 \cdot 50.01\,\text{N*m}\right) - \left(2.5 \cdot 50.01\,\text{N*m} + 3 \cdot 30\,\text{N*m} + 3 \cdot 20.01\,\text{N*m}\right)}{4}$$

13.2) Absolute Value of Moment at Quarter Point of Unbraced Beam Segment Formula

Evaluate Formula

Formula

$$M_A = \frac{\left(12.5 \cdot M'max\right) - \left(2.5 \cdot M'max + 4 \cdot M_B + 3 \cdot M_C\right)}{3}$$

Example with Units

$$79.9967\,\text{N*m} = \frac{\left(12.5 \cdot 50.01\,\text{N*m}\right) - \left(2.5 \cdot 50.01\,\text{N*m} + 4 \cdot 50.02\,\text{N*m} + 3 \cdot 20.01\,\text{N*m}\right)}{3}$$

13.3) Absolute Value of Moment at Three-Quarter Point of Unbraced Beam Segment Formula

Evaluate Formula

Formula

$$M_C = \frac{\left(12.5 \cdot M'max\right) - \left(2.5 \cdot M'max + 4 \cdot M_B + 3 \cdot M_A\right)}{3}$$

Example with Units

$$70.0067\,\text{N*m} = \frac{\left(12.5 \cdot 50.01\,\text{N*m}\right) - \left(2.5 \cdot 50.01\,\text{N*m} + 4 \cdot 50.02\,\text{N*m} + 3 \cdot 30\,\text{N*m}\right)}{3}$$

13.4) Critical Bending Coefficient Formula

Evaluate Formula

Formula

$$M_{coeff} = \frac{12.5 \cdot M'max}{\left(2.5 \cdot M'max\right) + \left(3 \cdot M_A\right) + \left(4 \cdot M_B\right) + \left(3 \cdot M_C\right)}$$

Example with Units

$$1.3157\,\text{N*m} = \frac{12.5 \cdot 50.01\,\text{N*m}}{\left(2.5 \cdot 50.01\,\text{N*m}\right) + \left(3 \cdot 30\,\text{N*m}\right) + \left(4 \cdot 50.02\,\text{N*m}\right) + \left(3 \cdot 20.01\,\text{N*m}\right)}$$

13.5) Critical Bending Moment for Simply Supported Open Section Beam Formula

Evaluate Formula

Formula

$$M_{cr} = \left(\frac{\pi}{L}\right) \cdot \sqrt{E \cdot I_y \cdot \left(\left(G \cdot J\right) + E \cdot C_w \cdot \left(\frac{\pi^2}{\left(L\right)^2}\right)\right)}$$

Example with Units

$$9.8021\,\text{N*m} = \left(\frac{3.1416}{10.04\,\text{cm}}\right) \cdot \sqrt{10.01\,\text{MPa} \cdot 10.001\,\text{kg·m²} \cdot \left(\left(100.002\,\text{N/m²} \cdot 10.0001\right) + 10.01\,\text{MPa} \cdot 10.0005\,\text{kg·m²} \cdot \left(\frac{3.1416^2}{\left(10.04\,\text{cm}\right)^2}\right)\right)}$$

13.6) Critical Bending Moment for Simply Supported Rectangular Beam Formula

Evaluate Formula

Formula

$$M_{Cr(Rect)} = \left(\frac{\pi}{Len}\right) \cdot \left(\sqrt{e \cdot I_y \cdot G \cdot J}\right)$$

Example with Units

$$740.5286\,\text{N*m} = \left(\frac{3.1416}{3\,\text{m}}\right) \cdot \left(\sqrt{50\,\text{Pa} \cdot 10.001\,\text{kg·m²} \cdot 100.002\,\text{N/m²} \cdot 10.0001}\right)$$

13.7) Critical Bending Moment in Non-Uniform Bending Formula

Evaluate Formula

Formula

$$M'_{cr} = \left(M_{coeff} \cdot M_{cr}\right)$$

Example with Units

$$13.2\,\text{N*m} = \left(1.32\,\text{N*m} \cdot 10\,\text{N*m}\right)$$

13.8) Elasticity Modulus given Critical Bending Moment of Rectangular Beam Formula

Evaluate Formula

Formula

$$e = \frac{\left(M_{Cr(Rect)} \cdot Len\right)^2}{\left(\pi^2\right) \cdot I_y \cdot G \cdot J}$$

Example with Units

$$50.0637\,\text{Pa} = \frac{\left(741\,\text{N*m} \cdot 3\,\text{m}\right)^2}{\left(3.1416^2\right) \cdot 10.001\,\text{kg·m²} \cdot 100.002\,\text{N/m²} \cdot 10.0001}$$

13.9) Minor Axis Moment of Inertia for Critical Bending Moment of Rectangular Beam Formula

Evaluate Formula

Formula

$$I_y = \frac{\left(M_{Cr(Rect)} \cdot Len\right)^2}{\left(\pi^2\right) \cdot e \cdot G \cdot J}$$

Example with Units

$$10.0137\,\text{kg·m²} = \frac{\left(741\,\text{N*m} \cdot 3\,\text{m}\right)^2}{\left(3.1416^2\right) \cdot 50\,\text{Pa} \cdot 100.002\,\text{N/m²} \cdot 10.0001}$$

13.10) Shear Elasticity Modulus for Critical Bending Moment of Rectangular Beam Formula

Evaluate Formula

Formula

$$G = \frac{\left(M_{Cr(Rect)} \cdot Len\right)^2}{\left(\pi^2\right) \cdot I_y \cdot e \cdot J}$$

Example with Units

$$100.1294\,\text{N/m²} = \frac{\left(741\,\text{N*m} \cdot 3\,\text{m}\right)^2}{\left(3.1416^2\right) \cdot 10.001\,\text{kg·m²} \cdot 50\,\text{Pa} \cdot 10.0001}$$

13.11) Unbraced Member Length given Critical Bending Moment of Rectangular Beam Formula

Evaluate Formula

Formula

$$Len = \left(\frac{\pi}{M_{Cr(Rect)}}\right) \cdot \left(\sqrt{e \cdot I_y \cdot G \cdot J}\right)$$

Example with Units

$$2.9981\,\text{m} = \left(\frac{3.1416}{741\,\text{N*m}}\right) \cdot \left(\sqrt{50\,\text{Pa} \cdot 10.001\,\text{kg·m²} \cdot 100.002\,\text{N/m²} \cdot 10.0001}\right)$$

Variables used in list of Structural Analysis of Beams Formulas above

- **a** Distance from A end *(Millimeter)*
- **A** Area of Cross-Section *(Square Millimeter)*
- **B** Width of Beam Section *(Millimeter)*
- C_w Warping Constant *(Kilogram Square Meter)*
- **D** Outer Depth *(Millimeter)*
- d_e Effective Depth of Beam *(Millimeter)*
- d_i Inner Depth *(Millimeter)*
- **e** Elastic Modulus *(Pascal)*
- **e'** Eccentricity of Load *(Millimeter)*
- **E** Modulus of Elasticity *(Megapascal)*
- **G** Shear Modulus of Elasticity *(Newton per Square Meter)*
- I_y Moment of Inertia about Minor Axis *(Kilogram Square Meter)*
- **J** Torsional Constant
- **k** Ratio between Plastic Moments
- **L** Unbraced Length of Member *(Centimeter)*
- **Len** Length of Rectangular Beam *(Meter)*
- M_A Moment at Quarter Point *(Newton Meter)*
- M_B Moment at Centerline *(Newton Meter)*
- M_C Moment at Three-quarter Point *(Newton Meter)*
- M_{coeff} Bending Moment Coefficient *(Newton Meter)*
- M_{cr} Critical Bending Moment *(Newton Meter)*
- M'_{cr} Non-Uniform Critical Bending Moment *(Newton Meter)*
- $M_{Cr(Rect)}$ Critical Bending Moment for Rectangular *(Newton Meter)*
- M_{max} Maximum Bending Moment *(Newton Meter)*
- M_p Plastic Moment *(Kilonewton Meter)*
- **M'max** Maximum Moment *(Newton Meter)*
- **P** Point Load *(Kilonewton)*
- **q** Uniformly Distributed Load *(Kilonewton per Meter)*
- **t** Dam Thickness *(Millimeter)*
- **U** Ultimate Load *(Kilonewton)*
- **x** Distance of point where Moment is Maximum *(Meter)*
- **x"** Point of Maximum Moment *(Meter)*
- **Z** Section Modulus for Eccentric Load on Beam *(Cubic Millimeter)*
- **σ** Stress of Beam *(Pascal)*
- **Φ** Diameter of Circular Shaft *(Millimeter)*

Constants, Functions, Measurements used in list of Structural Analysis of Beams Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288 *Archimedes' constant*
- Functions: **sqrt**, sqrt(Number) *A square root function is a function that takes a non-negative number as an input and returns the square root of the given input number.*
- Measurement: **Length** in Millimeter (mm), Meter (m), Centimeter (cm) *Length Unit Conversion*
- Measurement: **Volume** in Cubic Millimeter (mm^3) *Volume Unit Conversion*
- Measurement: **Area** in Square Millimeter (mm^2) *Area Unit Conversion*
- Measurement: **Pressure** in Pascal (Pa), Megapascal (MPa), Newton per Square Meter (N/m^2) *Pressure Unit Conversion*
- Measurement: **Force** in Kilonewton (kN) *Force Unit Conversion*
- Measurement: **Surface Tension** in Kilonewton per Meter (kN/m) *Surface Tension Unit Conversion*
- Measurement: **Moment of Inertia** in Kilogram Square Meter ($kg \cdot m^2$) *Moment of Inertia Unit Conversion*
- Measurement: **Moment of Force** in Newton Meter (N*m), Kilonewton Meter (kN*m) *Moment of Force Unit Conversion*

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