Important Strain Energy Formulas PDF

Formulas
Examples
with Units

List of 44
Important Strain Energy 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) Breadth for Rectangular Section to Maintain Stress as Wholly Compressive Formula

Evaluate Formula

Formula

$$t = 6 \cdot e'$$

Example with Units

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

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

Evaluate Formula

Formula

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

Example with Units

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

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

Evaluate Formula

Formula

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

Example with Units

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

5) 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

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

6) Eccentricity to Maintain Stress as Wholly Compressive Formula

Evaluate Formula

Formula

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

Example with Units

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

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

Evaluate Formula

Formula

$$Z = e' \cdot A$$

Example with Units

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

8) Strain Energy in Structural Members Formulas

8.1) Bending Moment using Strain Energy Formula

Evaluate Formula

Formula

$$M = \sqrt{U \cdot \frac{2 \cdot E \cdot I}{L}}$$

Example with Units

$$53.8799\,\text{kN*m} = \sqrt{136.08\,\text{N*m} \cdot \frac{2 \cdot 20000\,\text{MPa} \cdot 0.0016\,\text{m}^4}{3000\,\text{mm}}}$$

8.2) Length over which Deformation takes place given Strain Energy in Shear Formula

Evaluate Formula

Formula

$$L = 2 \cdot U \cdot A \cdot \frac{G_{Torsion}}{V^2}$$

Example with Units

$$2981.2627\,\text{mm} = 2 \cdot 136.08\,\text{N*m} \cdot 5600\,\text{mm}^2 \cdot \frac{40\,\text{GPa}}{143\,\text{kN}^2}$$

8.3) Length over which Deformation takes place given Strain Energy in Torsion Formula

Evaluate Formula

Formula

$$L = \frac{2 \cdot U \cdot J \cdot G_{Torsion}}{T^2}$$

Example with Units

$$3003.7289\,\text{mm} = \frac{2 \cdot 136.08\,\text{N*m} \cdot 4.1e{-}3\,\text{m}^4 \cdot 40\,\text{GPa}}{121.9\,\text{kN*m}^2}$$

8.4) Length over which Deformation takes place using Strain Energy Formula

Evaluate Formula

Formula

$$L = \left(U \cdot \frac{2 \cdot E \cdot I}{M^2} \right)$$

Example with Units

$$3008.9136\,\text{mm} = \left(136.08\,\text{N*m} \cdot \frac{2 \cdot 20000\,\text{MPa} \cdot 0.0016\,\text{m}^4}{53.8\,\text{kN*m}^2} \right)$$

8.5) Modulus of Elasticity with given Strain Energy Formula

Evaluate Formula

Formula

$$E = \left(L \cdot \frac{M^2}{2 \cdot U \cdot I} \right)$$

Example with Units

$$19940.7518\,\text{MPa} = \left(3000\,\text{mm} \cdot \frac{53.8\,\text{kN*m}^2}{2 \cdot 136.08\,\text{N*m} \cdot 0.0016\,\text{m}^4} \right)$$

8.6) Moment of Inertia using Strain Energy Formula

Evaluate Formula

Formula

$$I = L \cdot \left(\frac{M^2}{2 \cdot U \cdot E} \right)$$

Example with Units

$$0.0016\,\text{m}^4 = 3000\,\text{mm} \cdot \left(\frac{53.8\,\text{kN*m}^2}{2 \cdot 136.08\,\text{N*m} \cdot 20000\,\text{MPa}} \right)$$

8.7) Polar Moment of Inertia given Strain Energy in Torsion Formula

Evaluate Formula

Formula

$$J = \left(T^2\right) \cdot \frac{L}{2 \cdot U \cdot G_{Torsion}}$$

Example with Units

$$0.0041\,\text{m}^4 = \left(121.9\,\text{kN*m}^2\right) \cdot \frac{3000\,\text{mm}}{2 \cdot 136.08\,\text{N*m} \cdot 40\,\text{GPa}}$$

8.8) Shear Area given Strain Energy in Shear Formula

Evaluate Formula

Formula

$$A = \left(V^2\right) \cdot \frac{L}{2 \cdot U \cdot G_{Torsion}}$$

Example with Units

$$5635.1962\,\text{mm}^2 = \left(143\,\text{kN}^2\right) \cdot \frac{3000\,\text{mm}}{2 \cdot 136.08\,\text{N*m} \cdot 40\,\text{GPa}}$$

8.9) Shear Force using Strain Energy Formula

Evaluate Formula

Formula

$$V = \sqrt{2 \cdot U \cdot A \cdot \frac{G_{Torsion}}{L}}$$

Example with Units

$$142.5527\,\text{kN} = \sqrt{2 \cdot 136.08\,\text{N*m} \cdot 5600\,\text{mm}^2 \cdot \frac{40\,\text{GPa}}{3000\,\text{mm}}}$$

8.10) Shear Modulus of Elasticity given Strain Energy in Shear Formula

Evaluate Formula

Formula

$$G_{Torsion} = \left(V^2\right) \cdot \frac{L}{2 \cdot A \cdot U}$$

Example with Units

$$40.2514\,\text{GPa} = \left(143\,\text{kN}^2\right) \cdot \frac{3000\,\text{mm}}{2 \cdot 5600\,\text{mm}^2 \cdot 136.08\,\text{N*m}}$$

8.11) Shear Modulus of Elasticity given Strain Energy in Torsion Formula

Evaluate Formula

Formula

$$G_{Torsion} = \left(T^2\right) \cdot \frac{L}{2 \cdot J \cdot U}$$

Example with Units

$$39.9503\,\text{GPa} = \left(121.9\,\text{kN*m}^2\right) \cdot \frac{3000\,\text{mm}}{2 \cdot 4.1\text{e-}3\,\text{m}^4 \cdot 136.08\,\text{N*m}}$$

8.12) Strain Energy for Pure Bending when Beam rotates in One End Formula

Evaluate Formula

Formula

$$U = \left(E \cdot I \cdot \frac{\left(\theta \cdot \left(\frac{\pi}{180}\right)\right)^2}{2 \cdot L}\right)$$

Example with Units

$$111.3501\,\text{N*m} = \left(20000\,\text{MPa} \cdot 0.0016\,\text{m}^4 \cdot \frac{\left(15° \cdot \left(\frac{3.1416}{180}\right)\right)^2}{2 \cdot 3000\,\text{mm}}\right)$$

8.13) Strain Energy in Bending Formula

Evaluate Formula

Formula

$$U = \left(\left(M^2 \right) \cdot \frac{L}{2 \cdot E \cdot I} \right)$$

Example with Units

$$135.6769\,\text{N*m} = \left(\left(53.8\,\text{kN*m}^2 \right) \cdot \frac{3000\,\text{mm}}{2 \cdot 20000\,\text{MPa} \cdot 0.0016\,\text{m}^4} \right)$$

8.14) Strain Energy in Shear Formula

Evaluate Formula

Formula

$$U = \left(V^2 \right) \cdot \frac{L}{2 \cdot A \cdot G_{Torsion}}$$

Example with Units

$$136.9353\,\text{N*m} = \left(143\,\text{kN}^2 \right) \cdot \frac{3000\,\text{mm}}{2 \cdot 5600\,\text{mm}^2 \cdot 40\,\text{GPa}}$$

8.15) Strain Energy in Shear given Shear Deformation Formula

Evaluate Formula

Formula

$$U = \frac{A \cdot G_{Torsion} \cdot \left(\Delta^2 \right)}{2 \cdot L}$$

Example with Units

$$933.3333\,\text{N*m} = \frac{5600\,\text{mm}^2 \cdot 40\,\text{GPa} \cdot \left(0.005^2 \right)}{2 \cdot 3000\,\text{mm}}$$

8.16) Strain Energy in Torsion given Angle of Twist Formula

Evaluate Formula

Formula

$$U = \frac{J \cdot G_{Torsion} \cdot \left(\theta \cdot \left(\frac{\pi}{180} \right) \right)^2}{2 \cdot L}$$

Example with Units

$$570.6694\,\text{N*m} = \frac{4.1\text{e-}3\,\text{m}^4 \cdot 40\,\text{GPa} \cdot \left(15^\circ \cdot \left(\frac{3.1416}{180} \right) \right)^2}{2 \cdot 3000\,\text{mm}}$$

8.17) Strain Energy in Torsion given Polar MI and Shear Modulus of Elasticity Formula

Evaluate Formula

Formula

$$U = \left(T^2 \right) \cdot \frac{L}{2 \cdot J \cdot G_{Torsion}}$$

Example with Units

$$135.9111\,\text{N*m} = \left(121.9\,\text{kN*m}^2 \right) \cdot \frac{3000\,\text{mm}}{2 \cdot 4.1\text{e-}3\,\text{m}^4 \cdot 40\,\text{GPa}}$$

8.18) Stress using Hook's Law Formula

Evaluate Formula

Formula

$$\sigma = E \cdot \varepsilon_L$$

Example with Units

$$400\,\text{MPa} = 20000\,\text{MPa} \cdot 0.02$$

8.19) Torque given Strain Energy in Torsion Formula

Evaluate Formula

Formula

$$T = \sqrt{2 \cdot U \cdot J \cdot \frac{G_{Torsion}}{L}}$$

Example with Units

$$121.9757\,\text{kN*m} = \sqrt{2 \cdot 136.08\,\text{N*m} \cdot 4.1\text{e-}3\,\text{m}^4 \cdot \frac{40\,\text{GPa}}{3000\,\text{mm}}}$$

9) Strain Energy stored by the Member Formulas

9.1) Area of Member given Strain Energy Stored by Member Formula

Evaluate Formula

Formula

$$A = \frac{2 \cdot E \cdot U_{member}}{L \cdot \sigma^2}$$

Example with Units

$$5599.9995\,\text{mm}^2 = \frac{2 \cdot 20000\,\text{MPa} \cdot 301.2107\,\text{N*m}}{3000\,\text{mm} \cdot 26.78\,\text{MPa}^2}$$

9.2) Length of Member given Strain Energy Stored by Member Formula

Evaluate Formula

Formula

$$L = \frac{2 \cdot E \cdot U_{member}}{A \cdot \sigma^2}$$

Example with Units

$$2999.9997\,\text{mm} = \frac{2 \cdot 20000\,\text{MPa} \cdot 301.2107\,\text{N*m}}{5600\,\text{mm}^2 \cdot 26.78\,\text{MPa}^2}$$

9.3) Modulus of Elasticity of Member given Strain Energy Stored by Member Formula

Evaluate Formula

Formula

$$E = \frac{\left(\sigma^2\right) \cdot A \cdot L}{2 \cdot U_{member}}$$

Example with Units

$$20000.0019\,\text{MPa} = \frac{\left(26.78\,\text{MPa}^2\right) \cdot 5600\,\text{mm}^2 \cdot 3000\,\text{mm}}{2 \cdot 301.2107\,\text{N*m}}$$

9.4) Strain Energy Stored by Member Formula

Evaluate Formula

Formula

$$U_{member} = \left(\frac{\sigma^2}{2 \cdot E}\right) \cdot A \cdot L$$

Example with Units

$$301.2107\,\text{N*m} = \left(\frac{26.78\,\text{MPa}^2}{2 \cdot 20000\,\text{MPa}}\right) \cdot 5600\,\text{mm}^2 \cdot 3000\,\text{mm}$$

9.5) Stress of Member given Strain Energy Stored by Member Formula

Evaluate Formula

Formula

$$\sigma = \sqrt{\frac{2 \cdot U_{member} \cdot E}{A \cdot L}}$$

Example with Units

$$26.78\,\text{MPa} = \sqrt{\frac{2 \cdot 301.2107\,\text{N*m} \cdot 20000\,\text{MPa}}{5600\,\text{mm}^2 \cdot 3000\,\text{mm}}}$$

10) Strain Energy stored per unit Volume Formulas

10.1) Modulus of Elasticity of Member with known Strain Energy Stored per Unit Volume Formula

Evaluate Formula

Formula

$$E = \frac{\sigma^2}{2 \cdot U_{density}}$$

Example with Units

$$20000\,\text{MPa} = \frac{26.78\,\text{MPa}^2}{2 \cdot 17929.21\,\text{J/m}^3}$$

10.2) Strain Energy Stored per Unit Volume Formula

Evaluate Formula

Formula

$$U_{density} = \frac{\sigma^2}{2 \cdot E}$$

Example with Units

$$17929.21\,\text{J/m}^3 = \frac{26.78\,\text{MPa}^2}{2 \cdot 20000\,\text{MPa}}$$

10.3) Stress generated due to Strain Energy Stored per Unit Volume Formula

Evaluate Formula

Formula

$$\sigma = \sqrt{U_{density} \cdot 2 \cdot E}$$

Example with Units

$$26.78\,\text{MPa} = \sqrt{17929.21\,\text{J/m}^3 \cdot 2 \cdot 20000\,\text{MPa}}$$

11) Stress due to Formulas

11.1) Gradually Applied Load Formulas

11.1.1) Area given Stress due to gradually Applied Load Formula

Evaluate Formula

Formula

$$A = \frac{W_{Applied\ load}}{\sigma}$$

Example with Units

$$5601.1949\,\text{mm}^2 = \frac{150\,\text{kN}}{26.78\,\text{MPa}}$$

11.1.2) Load given Stress due to gradually Applied Load Formula

Evaluate Formula

Formula

$$W_{Applied\ load} = \sigma \cdot A$$

Example with Units

$$149.968\,\text{kN} = 26.78\,\text{MPa} \cdot 5600\,\text{mm}^2$$

11.1.3) Stress due to gradually Applied Load Formula

Evaluate Formula

Formula

$$\sigma = \frac{W_{Applied\ load}}{A}$$

Example with Units

$$26.7857\,\text{MPa} = \frac{150\,\text{kN}}{5600\,\text{mm}^2}$$

11.2) Impact Load Formulas

11.2.1) Stress due to Impact Load Formula

Evaluate Formula

Formula

$$\sigma = \left(\frac{W_{Applied\ load}}{A}\right) + \sqrt{\left(\frac{W_{Applied\ load}}{A}\right)^2 + \frac{2 \cdot W_{Applied\ load} \cdot h \cdot E}{A \cdot L}}$$

Example with Units

$$2097.1557\,\text{MPa} = \left(\frac{150\,\text{kN}}{5600\,\text{mm}^2}\right) + \sqrt{\left(\frac{150\,\text{kN}}{5600\,\text{mm}^2}\right)^2 + \frac{2 \cdot 150\,\text{kN} \cdot 12000\,\text{mm} \cdot 20000\,\text{MPa}}{5600\,\text{mm}^2 \cdot 3000\,\text{mm}}}$$

11.3) Shear Resilience Formulas

11.3.1) Modulus of Rigidity given Shear Resilience Formula

Evaluate Formula

Formula

$$G_{Torsion} = \frac{\tau^2}{2 \cdot SEV}$$

Example with Units

$$40\,\text{GPa} = \frac{55\,\text{MPa}^2}{2 \cdot 37812.5\,\text{J/m}^3}$$

11.3.2) Shear Resilience Formula

Evaluate Formula

Formula

$$SEV = \frac{\tau^2}{2 \cdot G_{Torsion}}$$

Example with Units

$$37812.5\,\text{J/m}^3 = \frac{55\,\text{MPa}^2}{2 \cdot 40\,\text{GPa}}$$

11.3.3) Shear Stress given Shear Resilience Formula

Evaluate Formula

Formula

$$\tau = \sqrt{2 \cdot SEV \cdot G_{Torsion}}$$

Example with Units

$$55\,\text{MPa} = \sqrt{2 \cdot 37812.5\,\text{J/m}^3 \cdot 40\,\text{GPa}}$$

11.4) Suddenly Applied Load Formulas

11.4.1) Area given Stress due to suddenly Applied Load Formula

Evaluate Formula

Formula

$$A = 2 \cdot \frac{W_{Applied\ load}}{\sigma}$$

Example with Units

$$11202.3898\,\text{mm}^2 = 2 \cdot \frac{150\,\text{kN}}{26.78\,\text{MPa}}$$

11.4.2) Load given Stress due to suddenly Applied Load Formula

Evaluate Formula

Formula

$$W_{Applied\ load} = \sigma \cdot \frac{A}{2}$$

Example with Units

$$74.984\,\text{kN} = 26.78\,\text{MPa} \cdot \frac{5600\,\text{mm}^2}{2}$$

11.4.3) Stress due to suddenly Applied Load Formula

Evaluate Formula

Formula

$$\sigma = 2 \cdot \frac{W_{Applied\ load}}{A}$$

Example with Units

$$53.5714\,\text{MPa} = 2 \cdot \frac{150\,\text{kN}}{5600\,\text{mm}^2}$$

Variables used in list of Strain Energy Formulas above

- **A** Area of Cross-Section *(Square Millimeter)*
- **D** Outer Depth *(Millimeter)*
- d_i Inner Depth *(Millimeter)*
- **e'** Eccentricity of Load *(Millimeter)*
- **E** Young's Modulus *(Megapascal)*
- $G_{Torsion}$ Modulus of Rigidity *(Gigapascal)*
- **h** Height of Crack *(Millimeter)*
- **I** Area Moment of Inertia *(Meter⁴)*
- **J** Polar Moment of Inertia *(Meter⁴)*
- **L** Length of Member *(Millimeter)*
- **M** Bending Moment *(Kilonewton Meter)*
- **SEV** Shear Resilience *(Joule per Cubic Meter)*
- **t** Dam Thickness *(Millimeter)*
- **T** Torque SOM *(Kilonewton Meter)*
- **U** Strain Energy *(Newton Meter)*
- $U_{density}$ Strain Energy Density *(Joule per Cubic Meter)*
- U_{member} Strain Energy stored by Member *(Newton Meter)*
- **V** Shear Force *(Kilonewton)*
- $W_{Applied\ load}$ Applied Load *(Kilonewton)*
- **Z** Section Modulus for Eccentric Load on Beam *(Cubic Millimeter)*
- **Δ** Shear Deformation
- ε_L Lateral Strain
- **θ** Angle of Twist *(Degree)*
- **σ** Direct Stress *(Megapascal)*
- **τ** Shear Stress *(Megapascal)*
- **Φ** Diameter of Circular Shaft *(Millimeter)*

Constants, Functions, Measurements used in list of Strain Energy 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) *Length Unit Conversion*
- Measurement: **Volume** in Cubic Millimeter (mm³) *Volume Unit Conversion*
- Measurement: **Area** in Square Millimeter (mm²) *Area Unit Conversion*
- Measurement: **Pressure** in Gigapascal (GPa) *Pressure Unit Conversion*
- Measurement: **Energy** in Newton Meter (N*m) *Energy Unit Conversion*
- Measurement: **Force** in Kilonewton (kN) *Force Unit Conversion*
- Measurement: **Angle** in Degree (°) *Angle Unit Conversion*
- Measurement: **Torque** in Kilonewton Meter (kN*m) *Torque Unit Conversion*
- Measurement: **Moment of Force** in Kilonewton Meter (kN*m) *Moment of Force Unit Conversion*
- Measurement: **Energy Density** in Joule per Cubic Meter (J/m³) *Energy Density Unit Conversion*
- Measurement: **Second Moment of Area** in Meter⁴ (m⁴) *Second Moment of Area Unit Conversion*
- Measurement: **Stress** in Megapascal (MPa) *Stress Unit Conversion*

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