Important Analysis using Limit State Method Formulas PDF

Formulas
Examples
with Units

List of 11
Important Analysis using Limit State Method Formulas

1) Doubly Reinforced Rectangular Sections Formulas

1.1) Bending Moment Capacity of Rectangular Beam Formula

Evaluate Formula

Formula

$$B_M = 0.90 \cdot \left(\left(A_{steel\ required} - A_{s'} \right) \cdot fy_{steel} \cdot \left(D_{centroid} - \left(\frac{a}{2} \right) \right) + \left(A_{s'} \cdot fy_{steel} \cdot \left(D_{centroid} - d' \right) \right) \right)$$

Example with Units

$$160.7422\,\text{kN*m} = 0.90 \cdot \left(\left(35\,\text{mm}^2 - 20\,\text{mm}^2 \right) \cdot 250\,\text{MPa} \cdot \left(51.01\,\text{mm} - \left(\frac{9.432\,\text{mm}}{2} \right) \right) + \left(20\,\text{mm}^2 \cdot 250\,\text{MPa} \cdot \left(51.01\,\text{mm} - 50.01\,\text{mm} \right) \right) \right)$$

1.2) Depth of Equivalent Rectangular Compressive Stress Distribution Formula

Evaluate Formula

Formula

$$a = \frac{\left(A_{steel\ required} - A_{s'} \right) \cdot fy_{steel}}{f_c \cdot b}$$

Example with Units

$$9.434\,\text{mm} = \frac{\left(35\,\text{mm}^2 - 20\,\text{mm}^2 \right) \cdot 250\,\text{MPa}}{15\,\text{MPa} \cdot 26.5\,\text{mm}}$$

2) Flanged Sections Formulas

2.1) Depth when Neutral Axis is in Flange Formula

Evaluate Formula

Formula

$$d_{eff} = K_d \cdot \frac{\beta 1}{1.18 \cdot \omega}$$

Example with Units

$$3.3966\,\text{m} = 100.2\,\text{mm} \cdot \frac{2.4}{1.18 \cdot 0.06}$$

2.2) Distance when Neutral Axis Lies in Flange Formula

Evaluate Formula

Formula

$$K_d = \frac{1.18 \cdot \omega \cdot d_{eff}}{\beta 1}$$

Example with Units

$$118\,\text{mm} = \frac{1.18 \cdot 0.06 \cdot 4\,\text{m}}{2.4}$$

2.3) Maximum Ultimate Moment when Neutral Axis Lies in Web Formula

Evaluate Formula

Formula

$$M_u = 0.9 \cdot \left(\left(A - A_{st} \right) \cdot fy_{steel} \cdot \left(d_{eff} - \frac{D_{equivalent}}{2} \right) + A_{st} \cdot fy_{steel} \cdot \left(d_{eff} - \frac{t_f}{2} \right) \right)$$

Example with Units

$$9E+9\,\text{N*m} = 0.9 \cdot \left(\left(10\,\text{m}^2 - 0.4\,\text{m}^2 \right) \cdot 250\,\text{MPa} \cdot \left(4\,\text{m} - \frac{25\,\text{mm}}{2} \right) + 0.4\,\text{m}^2 \cdot 250\,\text{MPa} \cdot \left(4\,\text{m} - \frac{99.5\,\text{mm}}{2} \right) \right)$$

2.4) Value of Omega if Neutral Axis is in Flange Formula

Evaluate Formula

Formula

$$\omega = K_d \cdot \frac{\beta 1}{1.18 \cdot d_{eff}}$$

Example with Units

$$0.0509 = 100.2\,\text{mm} \cdot \frac{2.4}{1.18 \cdot 4\,\text{m}}$$

3) Serviceability Limit States- Deflection and Cracking Formulas

3.1) Crack Control of Flexural Members Formulas

3.1.1) Equation for Crack Control Specific Limits Formula

Evaluate Formula

Formula

$$z = f_s \cdot \left(d_c \cdot A \right)^{\frac{1}{3}}$$

Example with Units

$$9043.907\,\text{lb*f/in} = 3.56\,\text{kN/m²} \cdot \left(1000.3\,\text{in} \cdot 1000.2\,\text{in²} \right)^{\frac{1}{3}}$$

3.1.2) Stress Calculated in Crack Control Formula

Evaluate Formula

Formula

$$f_s = \frac{z}{\left(d_c \cdot A \right)^{1}} / 3$$

Example with Units

$$3.2045\,\text{kN/m²} = \frac{900\,\text{lb*f/in}}{\left(1000.3\,\text{in} \cdot 1000.2\,\text{in²} \right)^{1}} / 3$$

4) Singly Reinforced Rectangular Sections Formulas

4.1) Bending Moment Capacity of Ultimate Strength given Area of Tension Reinforcement Formula

Evaluate Formula

Formula

$$B_M = 0.90 \cdot \left(A_{steel\ required} \cdot fy_{steel} \cdot \left(D_{centroid} - \left(\frac{a}{2} \right) \right) \right)$$

Example with Units

$$364.5652\,\text{kN*m} = 0.90 \cdot \left(35\,\text{mm²} \cdot 250\,\text{MPa} \cdot \left(51.01\,\text{mm} - \left(\frac{9.432\,\text{mm}}{2} \right) \right) \right)$$

4.2) Bending Moment Capacity of Ultimate Strength given Beam Width Formula

Evaluate Formula

Formula

$$B_M = 0.90 \cdot \left(A_{steel\ required} \cdot fy_{steel} \cdot D_{centroid} \cdot \left(1 + \left(0.59 \cdot \frac{\left(\rho_T \cdot fy_{steel} \right)}{f_c} \right) \right) \right)$$

Example with Units

$$51.3578\,\text{kN*m} = 0.90 \cdot \left(35\,\text{mm²} \cdot 250\,\text{MPa} \cdot 51.01\,\text{mm} \cdot \left(1 + \left(0.59 \cdot \frac{\left(12.9 \cdot 250\,\text{MPa} \right)}{15\,\text{MPa}} \right) \right) \right)$$

4.3) Distance from Extreme Compression Surface to Neutral Axis in Compression Failure Formula

Evaluate Formula

Formula

$$c = \frac{0.003 \cdot d_{eff}}{\left(\frac{f_{TS}}{E_s} \right) + 0.003}$$

Example with Units

$$157.4785\,\text{in} = \frac{0.003 \cdot 4\,\text{m}}{\left(\frac{24\,\text{kgf/m²}}{1000\,\text{ksi}} \right) + 0.003}$$

Variables used in list of Analysis using Limit State Method Formulas above

- **a** Depth of Rectangular Stress Distribution *(Millimeter)*
- **A** Area of Tension Reinforcement *(Square Meter)*
- **A** Effective Tension Area of Concrete *(Square Inch)*
- $A_{s'}$ Area of Compression Reinforcement *(Square Millimeter)*
- A_{st} Tensile Steel Area for Strength *(Square Meter)*
- $A_{steel\ required}$ Area of Steel Required *(Square Millimeter)*
- **b** Beam Width *(Millimeter)*
- B_M Bending Moment of Considered Section *(Kilonewton Meter)*
- **c** Neutral Axis Depth *(Inch)*
- **d'** Effective Cover *(Millimeter)*
- d_c Thickness of Concrete Cover *(Inch)*
- $D_{centroid}$ Centroidal Distance of Tension Reinforcement *(Millimeter)*
- d_{eff} Effective Depth of Beam *(Meter)*
- $D_{equivalent}$ Equivalent Depth *(Millimeter)*
- E_s Modulus of Elasticity of Steel *(Kilopound Per Square Inch)*
- f_c 28 Day Compressive Strength of Concrete *(Megapascal)*
- f_s Stress in Reinforcement *(Kilonewton per Square Meter)*
- f_{TS} Tensile Stress in Steel *(Kilogram-Force per Square Meter)*
- fy_{steel} Yield Strength of Steel *(Megapascal)*
- K_d Distance from Compression Fiber to NA *(Millimeter)*
- M_u Maximum Ultimate Moment *(Newton Meter)*
- t_f Flange Thickness *(Millimeter)*
- **z** Crack Control Limits *(Pound-Force per Inch)*
- **β1** Constant β1
- ρ_T Tension Reinforcement Ratio
- **ω** Value of Omega

Constants, Functions, Measurements used in list of Analysis using Limit State Method Formulas above

- Measurement: **Length** in Millimeter (mm), Meter (m), Inch (in)
  Length Unit Conversion
- Measurement: **Area** in Square Millimeter (mm²), Square Meter (m²), Square Inch (in²)
  Area Unit Conversion
- Measurement: **Pressure** in Kilonewton per Square Meter (kN/m²), Kilogram-Force per Square Meter (kgf/m²), Kilopound Per Square Inch (ksi)
  Pressure Unit Conversion
- Measurement: **Surface Tension** in Pound-Force per Inch (lb*f/in)
  Surface Tension Unit Conversion
- Measurement: **Moment of Force** in Kilonewton Meter (kN*m), Newton Meter (N*m)
  Moment of Force Unit Conversion
- Measurement: **Stress** in Megapascal (MPa)
  Stress Unit Conversion

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