

## ASTM Bolt Torque / Preload Calculator

This module implements an ASTM structural bolt torque / preload calculator for UNC threaded fasteners. It is intended as a quick engineering aid for estimating bolt preload as a function of specified installation torque, surface friction, and ASTM designation, and for checking the resulting preload against proof and tensile capacities.

### 1. Usage

1. Open the ASTM bolt module in a web browser.
2. In the left panel (Inputs), select the UNC thread size from the “Thread Size” dropdown. On page load, the default is 3/4 – 10 UNC.
3. Select the ASTM designation from the “ASTM Designation” dropdown (e.g., A307, A325 Type 1, A490 Type 1). The selected designation controls the proof, yield, and ultimate tensile strengths used in the calculations.
4. Specify the positive and negative torque tolerance values in percent. These define the upper and lower bounds on applied torque relative to the nominal torque value.
5. Enter the minimum and maximum thread friction coefficients  $\mu$ , and the minimum and maximum bearing (under-head) friction coefficients  $\mu$ . These represent the expected range of friction conditions during tightening.
6. Enter the specified installation torque in in-lb.
7. All results in the right-hand panel (Results) update automatically whenever an input is changed.

### Input Summary

**Thread Size (UNC):** Nominal UNC thread designation (e.g., 3/4 – 10 UNC).

**ASTM Designation:** ASTM structural bolt specification (A307, A325 Type 1/2/3, A354 BC/BD, A449, A490 Type 1/3). Controls the allowable stresses.

**(+) Torque Tolerance / (-) Torque Tolerance:** Percent deviation above and below the nominal torque used to define maximum and minimum torque.

**Thread  $\mu$  (min / max):** Minimum and maximum thread friction coefficients.

**Head  $\mu$  (min / max):** Minimum and maximum friction coefficients under the bolt head or nut bearing surface.

**Specified Torque:** Nominal installation torque in in-lb.

### Outputs Summary

**Diameter:** Nominal bolt diameter (in).

**TPI:** Threads per inch.

**Tensile Area:** Thread tensile stress area computed from the UNC geometry (in<sup>2</sup>).

**Proof / Yield / Tensile Stress:** Allowable proof, yield, and ultimate tensile stresses derived from the selected ASTM specification (psi).

**Proof / Yield / Tensile Load:** Corresponding capacities in force units (lb), obtained by multiplying stress by tensile stress area.

**Minimum / Maximum Preload:** Minimum and maximum bolt preload estimates based on torque, friction range, and tolerances (lb).

**Preload / Proof Load:** Ratio of maximum predicted preload to proof load. Values > 1.0 indicate that the maximum preload exceeds proof.

**Preload / Min Tensile:** Ratio of maximum predicted preload to minimum tensile capacity. Values > 1.0 indicate that the maximum preload exceeds ultimate capacity.

**Nut Factor K:** Effective nut factor based on thread geometry and average friction coefficients.

## 2. Methodology

### 2.1 Geometry and Tensile Stress Area

The UNC thread geometry is taken from a tabulated dataset of thread designations, diameters, and threads-per-inch (TPI). For each selected thread size, the major diameter  $d$  and threads-per-inch  $N$  are known.

The thread tensile stress area  $A_t$  is computed using the standard approximation for unified inch threads:

$$A_t = 0.7854 \times (d - 0.9743 / N)^2$$

where  $d$  is the nominal major diameter (in) and  $N$  is TPI. This expression approximates the minor diameter at the root of the thread and uses a circular core area with a correction factor for the V-thread profile.

### 2.2 Material Strengths from ASTM Specification

The module maps each ASTM designation to a set of nominal proof, yield, and tensile strengths (in psi). These values are representative of typical values given in ASTM standards and design manuals for structural bolts. The values may depend on bolt diameter (e.g., larger diameters sometimes have lower specified strengths).

For example (approximate values):

ASTM	Proof (psi)	Yield (psi)	Tensile (psi)
A307	33,000	36,000	60,000
A325 ( $\leq 1"$ )	85,000	92,000	120,000
A490	120,000	130,000	150,000

The exact values used in the code may be slightly simplified or averaged and should be checked against the current ASTM standard if the results are being used for final design.

### 2.3 Capacity Calculations

Given the tensile stress area  $A_t$  and the material stresses, the load capacities are computed as:

$$\mathbf{Proof\ Load = \sigma_{proof} \times A_t}$$

$$\mathbf{Yield\ Load = \sigma_{yield} \times A_t}$$

$$\mathbf{Tensile\ Load = \sigma_{tensile} \times A_t}$$

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where  $\sigma_{proof}$ ,  $\sigma_{yield}$ , and  $\sigma_{tensile}$  are the proof, yield, and ultimate tensile stresses respectively (psi), and  $A_t$  is in  $\text{in}^2$ , yielding loads in lb.

### 2.4 Torque–Tension Relationship

The module implements a more detailed thread mechanics model rather than a single constant K factor. The model accounts for thread friction, bearing friction, and the thread helix angle. The lead L is the reciprocal of TPI:

$$\mathbf{L = 1 / N}$$

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The pitch diameter is approximated as:

$$D_m = d - 0.649519 \times L$$

The half-angle of the thread flank is taken as  $30^\circ$ , so the secant of the flank angle  $\alpha$  is approximately:

$$\mathbf{sec(\alpha) \approx 1.1547}$$

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A thread factor TF is computed as a function of friction and geometry:

$$\mathbf{T_F = 0.5 \times D_m \times (L + \pi \mu_t D_m sec(\alpha)) / (\pi D_m - \mu_t L sec(\alpha))}$$

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where  $\mu_t$  is the thread friction coefficient,  $D_m$  is the pitch diameter, and L is the lead. An additional bearing friction torque term is added:

$$\mathbf{T_{bearing} = \mu_b \times 1.25 \times d / 2}$$

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where  $\mu_b$  is the under-head friction coefficient and d is the nominal diameter. The total torque required to produce a preload P is approximated by:

$$\mathbf{T \approx P \times (T_F + T_{bearing})}$$

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In the module, this relationship is inverted by computing an effective torque factor from friction and geometry, then dividing the specified torque by this factor to obtain an

estimated preload. Separate thread factors are computed for the minimum and maximum assumed friction to produce a range of preloads.

### 2.5 Torque Tolerances and Preload Range

The user-specified nominal torque  $T$  and torque tolerances (+%) and (-%) are used to compute a range of possible applied torques:

$$T_{max} = (1 + T_{plus} / 100) \times T$$

$$T_{min} = (1 - T_{minus} / 100) \times T$$

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The maximum preload is estimated using the maximum torque  $T_{max}$  and the minimum friction ( $\mu_{t,min}$ ,  $\mu_{b,min}$ ), which gives the highest preload for a given torque. The minimum preload is estimated using the minimum torque  $T_{min}$  and the maximum friction ( $\mu_{t,max}$ ,  $\mu_{b,max}$ ), which gives the lowest preload for the least torque.

This provides a realistic range of preloads for a given torque setting and friction variability.

### 2.6 Safety Ratios

Two dimensionless safety ratios are reported:

$$Preload / Proof Load = P_{max} / P_{proof}$$

$$Preload / Min Tensile = P_{max} / P_{tensile}$$

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where  $P_{max}$  is the maximum predicted preload,  $P_{proof}$  is the proof load, and  $P_{tensile}$  is the tensile capacity. Values greater than 1.0 indicate that the maximum predicted preload exceeds the corresponding limit.

### 2.7 Nut Factor K

For reference, the module also outputs an effective nut factor  $K$ , computed by combining geometry and average friction coefficients:

$$\tan(\lambda) = L / (\pi Dm)$$

$$K = 0.5 \times (Dm / d) \times (\tan(\lambda) + \mu_{t,avg} \sec(\alpha)) / (1 - \mu_{t,avg} \tan(\lambda) \sec(\alpha)) + 0.625 \mu_{b,avg}$$

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where  $\mu_{t,avg}$  and  $\mu_{b,avg}$  are the averages of the minimum and maximum thread and bearing friction coefficients. This nut factor can be compared to simplified rules of thumb (e.g.,  $K \approx 0.18$ – $0.25$  for typical steel bolts) and offers insight into how friction and geometry influence the torque–tension relationship.

## 3. Limitations and Notes

Key limitations and assumptions include:

- Strength values for each ASTM designation are representative and may be simplified. Always verify against the current ASTM standard if using this tool for final design.
- The tensile stress area formula for UNC threads is an approximation. For critical work, consult the latest Machinery's Handbook or ASME / SAE standards.
- The torque–tension model assumes single-start threads, uniform friction, and does not account for effects such as bending, nonuniform load distribution, or joint relaxation.
- The preload range is sensitive to friction assumptions. Real joints may show even wider scatter in preload due to tool calibration, surface condition, lubrication, and joint stiffness.
- This calculator is intended as an engineering aid and educational tool, not as a substitute for project-specific design, testing, or code compliance.

#### 4. References

- **ASTM International.** ASTM A307, A325, A354, A449, A490 and related standards for structural bolts.
- **ISO / SAE / ASME handbooks:** standard data and formulas for unified screw threads, tensile stress areas, and bolt strength values.
- **Oberg, E., et al.** Machinery's Handbook. Industrial Press.
- **Bickford, J. H.** An Introduction to the Design and Behavior of Bolted Joints. CRC Press.
- **VDI 2230.** Systematic Calculation of High Duty Bolted Joints. Verein Deutscher Ingenieure.