

APPENDIX E – METRIC CONVERSION

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[E.1 Introduction](#)

The International System of Units (SI), a modern version of the metric system of measurement, is being adopted throughout the world. To remain competitive in the global economy, Congress determined the United States must convert to SI.

FHWA was planning to require ODOT and local agencies to submit contract documents in metric by September 30, 1996. Congress then postponed the implementation date to September 30, 2000 and later completely removed the requirement.

After removal of the Metric requirement, most states have reverted back to English units or dual units.

ODOT believes it is important to be in alignment with other state DOT's and local government partners. ODOT began converting back to English units in late 2002 and began contracting State projects in English units in early 2004.

This section has been retained to provide a guide to the units and conversions most commonly used by the Bridge Engineering Section during the Metric era. This section may help with the interpretation of plans produced during the Metric era.

E.2 Basic Units

There are five metric "basic units" that concern bridge design and construction (see Figure E.2).

BASIC ODOT BRIDGE DESIGN METRIC UNITS

Quantity	Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Temperature	Celsius	°C
Plane angles	degree, minute, second	0°, 0', 0"

Figure E.2

E.2.1 Decimal Prefixes

Many numbers resulting from metric calculations are too large or small to be practically used. Three decimal prefixes are commonly used with the base units to produce manageable numbers (see Figure E.2.1).

DECIMAL PREFIXES

Prefix	Symbol	Magnitude	Expression
Mega	M	10 ⁶	1 000 000 (one million)
Kilo	k	10 ³	1000 (one thousand)
Milli	m	10 ⁻³	0.001 (one thousandth)

Figure E.2.1

E.3 Derived Units

In addition to the five basic units, there are three metric units derived from the basic units that are used frequently in structural calculations (see Figure E.3).

DERIVED UNITS

Quantity	Name	Symbol	Expression
Force	Newton	N	N = kg•m/s ²
Pressure, stress	Pascal	Pa	Pa = N/m ²
Energy	Joule	J	J = N•m

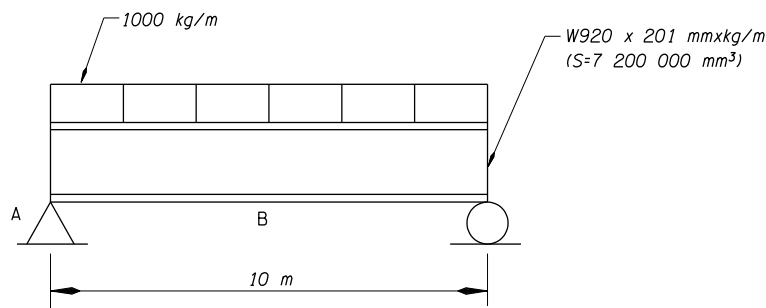
Figure E.3

E.3.1 Force

In order to perform metric calculations properly, it is important to understand the distinction between mass "kg" and force "N".

In the metric system, there are separate units for mass "kg" and force "N". Mass indicates the quantity of matter in an object. Force or "force of gravity" is the acceleration due to gravity the object experiences in a particular environment. The mass must be converted to force before computing structural reactions, shears, moments, or internal stresses. Force "N" = mass times acceleration due to gravity. The metric acceleration of gravity on the earth's surface is 9.807 m/s² (i.e., 32.2 ft/s² x 0.3048 m/ft). One newton = one kilogram x (one meter)/(one second)².

For example, a simply supported beam 10 meters long with a mass of 1000 kg/m would have a total mass of 10 000 kg (see Figure E.3.1). However, the dead load or force on a beam, on the earth's surface, used to calculate the reactions, shears, moments, etc. would be 1000 x 9.807 = 9807 N/m. The distinction between mass and force in structural calculations is very important.



Quantity	Inch-Pound Units	Metric Units
Dead Load (Force)	= 672+135 = 807 lb/ft	= (1000+201) (9.807) = 11 777.8 N/m
$V_A = wl/2$	= (807)(32.808)/2 = 13,238 lb	= (11 777.8) (10)/2 = 58 889 N
$M_B = wl^2/8$	= (807)(32.808) ² /8 = 108,578 ft-lb	= (11 777.8)(10) ² /8 = 147 222 N•m
$F_B = M/s$	= (108,578)(12in/ft)/440 = 2961 psi	=(147 222)(10 ⁹ mm ³ /m ³)/7210x10 ³ = 20 419 000 Pa = 20 419 kPa = 20.419 MPa

Note: lb is understood to be lb-force.

Figure E.3.1

E.3.2 Stress

The pascal is not universally accepted as the only unit of stress. Because steel section properties are expressed in millimeters, it may be more convenient to express stress in a derivative of pascals; that is in newtons per square millimeter (1 N/mm² = 1 MPa).

E.3.3 Energy

Although the joule is a standard metric unit, it is typically not used in structural design. Moments are always expressed in terms of Nm, or the derivative kN•m.

E.4 Metric Conversion Factors

Figure E.4, is intended to provide common conversion factors and show typical equivalent conversion units between "inch-pound" and "metric" values. The factors will allow the designer to get a feel for the magnitude of metric units as compared to inch-pound units.

COMMON METRIC UNITS AND CONVERSIONS

Quantity	From Inch-Pound Units	To Metric Units	Multiply by
Length	mile	km	1.609 344
	foot	m	0.304 8
	inch	mm	25.4
Area	square mile	km ²	2.590 00
	acre	m ²	4 046.87
	square yard	m ²	0.836 127 4
	square foot	m ²	0.092 903 0
	square inches	mm ²	645.160
Volume	cubic yard	m ³	0.764 555
	cubic foot	m ³	0.028 316 8
Mass*	Lb	kg	0.453 592
	Ton	kg	0.907 184
Mass/unit length*	P/lf	kg/m	1.488 16
Mass/unit area*	P/ff	kg/m ²	4.882 43
Mass density*	P/cf	kg/m ³	16.018 5
Force	Lb	N	4.448 22
	metric kg	kN	9.806 65
	kip	kN	4.448 22
Force/unit length	P/lf	n/m	14.593 9
	K/lf	kN/m	14.593 9
Pressure, stress, Modulus of elasticity	P/ff	Pa	47.880 3
	ksf	kPa	47.880 3
	psi	kPa	6.894 76
	ksi	MPa	6.894 76
Bending moment, torque, moment of force	ft-lb	N•m	1.355 82
	ft-kip	kN•m	1.355 82
Moment of inertia	in ⁴	mm ⁴	416 231
Section modulus	in ³	mm ³	16 387.064
Temperature	°F	°C	5/9 (°F - 32)

*Note: The Inch-Pound Units system using "a mass which weighs such and such pounds" and converting to true Metric Units masses.

Figure E.4

E.5 Metric Procedural Rules

E.5.1 Writing Metric Symbols and Names

- Unit symbols should be in lower case except for newton (N), pascal (Pa), and mega (M).
- Unit names should always be printed in lower case, i.e., newton, pascal, kilogram.
- Do not use the plural of unit symbols (write 45 kg, not 45 kgs), but do use the plural of written unit names (several kilograms).
- Leave a space between the numeral and a unit symbol. Write "70 kg" or "30 °C", not "70kg" or "30°C".
- Do not use a period after the symbol. Write "70 kg", not "70 kg.", except when it comes at the end of a sentence.
- Indicate the product of two or more units in symbolic form by using a dot between the symbols, i.e., N•m or kg•m.
- Do not mix names and symbols. Write N•m or newton meter, not N•meter or newton•m.
- Do not leave a space between a decimal prefix and a unit symbol. Write "MPa" or "kN•m", not "M Pa" or "k N•m".

E.5.2 Writing Numbers

- Use decimals, not fractions. Write 0.75 m, not 3/4 m.
- Use a zero before the decimal point for values less than one. Write 0.65 kg, not .65 kg.
- Spaces are frequently used to separate blocks of three digits either side of the decimal point. Never use a comma to separate the blocks. For plan dimensions, it will be acceptable to either insert or omit the space. Write 16 387.064 or 16387.064; but never 16,387.064.

E.5.3 Conversions and Rounding

When converting from inch-pound units to metric units, round the metric value to the same number of digits as there were in the inch-pound number, i.e., $235.75 \text{ lb} \times 0.453 592 \text{ kg/lb} = 106.9343 \text{ kg}$ which should be rounded to 106.93 kg.

Also see *ASTM E380*, Section 5, for general guidelines.

E.6 Bridge Plan and Preparation Guidelines

E.6.1 Plan Dimensions

For dimensions and elevations use:

- Millimeters in standard drawings and structural details.

- Meters for plan dimensions (structure and span lengths, structure width, lane and shoulder widths, etc.) and other long dimensions.
- Meters to three places for elevations, preceded with the abbreviation El. (e.g., El. 309.564).

To eliminate the repetitive use of (mm) and (m), these will not be used for dimensions in millimeters and elevations in meters. Meter dimensions should be followed by the symbol (m).

The following note should be shown on the plans, "All dimensions are in millimeters (mm) and all elevations are in meters (m), except as noted."

At all locations in notes, etc. use (mm) and (m) notations.

E.6.2 Reinforcing Steel

A new series of soft converted reinforcing steel sizes should be used. Figures E.6.2A and E.6.2B on the following page show the metric properties for conventional and prestressing steel. The equivalent area in square inches is shown for comparison purposes. The metric bar size is roughly equal to the bar diameter in millimeters.

The length of straight bars should be shown in 100 millimeter increments where possible. Bent bars should be detailed to the nearest 20 millimeter total length.

E.6.3 Fasteners

Fasteners are to be called out as a soft conversion to the nearest 0.1 mm. Use the appropriate English specifications for bolts, nuts and washers.

E.6.4 Structural Steel

The structural steels called out in ODOT plans and specifications all have metric equivalents. These equivalent specifications have the same number (AASHTO or ASTM) followed by a capital M; e.g. AASHTO M 270M or ASTM A 709M.

Structural steel shapes will be a soft conversion. AISC conversion tables are available.

Plate thickness should be a soft conversion and called out to the nearest 0.1 mm.

Normally plate widths should be a hard metric conversion. In some situations it may be appropriate to use soft converted plate widths. If repetitious pieces have a dimension that can use a common English plate width, one plate cut can be avoided and it will be more economical to fabricate the item.

REINFORCING BAR COMPARISON

Metric Bar	English Bar	English Dia. (in)	English Area (in ²)	English Weight (lb/ft)	Metric Dia. (mm)	Metric Area (mm ²)	Metric Mass (kg/m)
#10	#3	0.375	0.11	0.376	9.5	71	0.560
#13	#4	0.500	0.20	0.668	12.7	129	0.994
#16	#5	0.625	0.31	1.043	16.0	199	1.552
#19	#6	0.750	0.44	1.502	19.1	284	2.235
#22	#7	0.875	0.60	2.044	22.2	387	3.042
#25	#8	1.000	0.79	2.670	25.4	510	3.973
#29	#9	1.128	1.00	3.400	28.7	645	5.060
#32	#10	1.270	1.27	4.303	32.3	819	6.404
#36	#11	1.410	1.56	5.313	35.8	1006	7.907
#43	#14	1.693	2.25	7.650	43.0	1452	11.38
#57	#18	2.257	4.00	13.60	57.3	2581	20.24

Figure E.6.2A

Stock Bar Lengths

- #10 – 6.09 and 12.19 m
- #13 & # 16 – 6.09, 9.14 and 12.19 m
- #19 thru #36 – 18.28 m
- #43 thru #57 – 18.28, 21.33 and 24.38 m

PRESTRESSING STEEL - Conversion of prestressing steel should be a soft conversion using the table below. Make sure standard drawings and plan detail sheets specify the correct strand diameters.

SEVEN WIRE, UNCOATED STRAND

(270 Grade Low-Relaxation AASHTO M203 (ASTM A-416))

Metric Size (mm)	English Size (inch)	Metric Ult. (kN)	English Ult. (lbs)	Metric Area (mm ²)	English Area (in ²)	Metric Mass (kg/m)	English Weight (lb/ft)
9.53	3/8	102.3	23,000	54.84	0.085	0.432	0.290
11.11	7/16	137.9	31,000	74.19	0.115	0.582	0.390
12.70	1/2	183.7	41,300	98.71	0.153	0.775	0.520
15.24	0.600	260.7	58,600	140.0	0.217	1.102	0.740

Figure E.6.2B

E.7 Miscellaneous Common Conversions

	Inch-Pound	Metric
Dead Loads:		
Future Wearing Surface	25 psf	1.2 kN/m ²
Reinforced Concrete	150 pcf	23.6 kN/m ³
Soil	120 pcf	18.9 kN/m ³
Material Strengths:		
Concrete (f'c)	3300 psi	22.8 MPa, Equiv. to 25 MPa
	4000 psi	27.6 MPa, Equiv. to 30 MPa
	4500 psi	31.0 MPa, Equiv. to 35 MPa
	5000 psi	34.5 MPa, Equiv. to 35 MPa
	5500 psi	37.9 MPa, Equiv. to 40 MPa
	6000 psi	41.4 MPa, Equiv. to 45 MPa
	6500 psi	44.8 MPa, Equiv. to 45 MPa
	7000 psi	48.3 MPa, Equiv. to 50 MPa
Reinforcing Steel:		
Grade 40	40 ksi	275.8 MPa, Equiv. to 300 MPa
Grade 60	60 ksi	413.7 MPa, Equiv. to 420 MPa
Grade 80	80 ksi	551.6 MPa, Equiv. to 550 MPa
Structural Steel:		
Grade 36	36 ksi	248.2 MPa, Equiv. to 250 MPa
Grade 50	50 ksi	344.7 MPa, Equiv. to 345 MPa
Grade 70	70 ksi	482.6 MPa, Equiv. to 480 MPa
Reinforcing Steel Clearances		
	1.0 in	25 mm
	1.5 in	40 mm
	2.0 in	50 mm
	2.5 in	65 mm
	3.0 in	75 mm
	4.0 in	100 mm
Aggregate sizes		
	1-1/2 in	37.5 mm
	1 in	25.4 mm
	3/4 in	19.0 mm
	3/8 in	9.5 mm
Deck Concrete		
	4500 psi	Equivalent to Class 30 (4350 psi)
Approach Slab Concrete		
	3300 or 4500 psi	Equivalent to Class 25 (3626 psi) or 30 (4350 psi)
Minor Structure Concrete		
	3000 psi	Class 20 (2901 psi)