New Jersey Department of Transportation

GUIDE TO METRICATION

November 1994

Prepared by:

EDWARDS AND KELCEY, INC.

TABLE OF CONTENTS

q:\projst\941056\reports\dotguid.toc

SECTION 1 - INTRODUCTION

1.1 PURPOSE OF GUIDE

The New Jersey Department of Transportation (NJDOT) is committed to achieving the FHWA mandate for producing metric designs and letting metric contracts by **September 30, 1996**. In order to provide early guidance on metric design and to support designers who are already working on metric design projects, this Interim Guide has been prepared.

The intent of the Interim Guide is to provide basic metric guidance needed for design. The Guide does not include information on design principles and procedures, nor does it establish NJDOT policies. The Guide focuses instead on providing the metric data needed to produce a metric design within the framework of existing Department policies and practices, and will serve as a resource during the implementation of metrication.

1.2 HISTORICAL AND LEGISLATIVE BACKGROUND

In order to improve the competitiveness of American business and industry in the world marketplace, the Federal Government has designated the **metric system** as the preferred system of weights and measures for United States trade and commerce. Actually, in 1893, the United States adopted the metric system as the fundamental standard for length and mass. However, the modern version of the metric system was formally established in 1960 when the United States and other countries created the **"International System of Units (SI)"** at the 11th General Conference on Weights and Measures. The following are summaries of the federal statutes and guidelines in effect:

- Metric Conversion Act of 1975 - declared a national policy of coordinating the increasing use of the metric system, and a U.S. Metric Board was established to coordinate voluntary conversion. However, public opposition effectively blocked the voluntary conversion efforts, and metric conversion activities were suspended.

- The Omnibus Trade and Competitiveness Act of 1988 (Public Law 100-418) - Section 5164 of this act declared the metric system as the preferred system of weights and measures for U.S. trade and commerce and required each federal agency to convert to the metric system.

- Presidential Executive Order No. 12770, Metric Usage in Federal Government Programs - signed by President George Bush on July 25, 1991 and implemented both the Metric Conversion Act of 1975 and the Omnibus Trade and Competitiveness Act of 1988. This order directs Federal agencies to take all appropriate measures within their authority to carry out the provisions of the conversion, and gave authority and responsibility to the Secretary of Commerce to guide the federal metrication transition.

- U.S. DOT Metric Conversion Planning Guidelines issued in 1990 and amended in 1991 and 1992 required the nine U.S. DOT agencies to develop plans for conversion to the extent possible.

- Federal Highway Administration (FHWA) developed a conversion plan and a timetable approved in 1991 to lead to complete metric implementation by **September 30, 1996**.

- Federal Highway Administration (FHWA) complied with the requirements of the Omnibus Trade and Competitiveness Act of 1988 by publishing the following policies in the Federal Register on June 11, 1992:

  - After September 30, 1996, FHWA will only authorize funding for projects developed in metric units.

  - The deadline for FHWA reports to be in metric units will be those submitted after September 30, 1994. These reports include the Intermodal Surface Transportation Efficiency Act (ISTEA) Management Systems and Highway Performance Monitoring System (HPMS).

1.3 METRIC ASSISTANCE

Several metric chairs have been established within the various bureaus of the NJDOT to coordinate the metric conversion effort. They may be contacted at the telephone numbers indicated below:

NJDOT Metric Coordinator	Charles Miller	609/530-2523
Structures	Robert DiBartolo	609/530-2551
Geometrics	Robert Malinoski	609/530-3808
Geotech	John Jamerson	609/530-3733
Electrical	Jim Takacs	609/530-2609
Landscape	Henry Renelli	609/530-5671
Traffic	George Strathern	609/530-2626
Construction	Frank Stia	609/530-5502
Materials	John Zim	609/530-2303
CADD	John Ciemnecki	609/530-5156
Specifications and Std Details	Michael Cronin or	609/530-2573
	Frank Cocchiola	609/530-2572
Design Procedures	Steve Lavelle	609/530-2460
Photogrammetry	Lou Marchuk	609/530-5641
Drainage	Lad Szalaj	609/530-3806
Sample Plans	Sarah Alu	609/530-2710
BAMS	Andy Kuchtyak	609/530-5631
Electronic Bidding	Andy Kuchtyak	609/530-5631
FHWA	Daniel Clark	609/989-2279
OTIS	Art Coughlin	609/633-0365
Edwards and Kelcey, Inc.	Todd N Schickel	201/267-0555X1344

SECTION 2 - BASIC METRICS

The metric system is defined as a "coherent" system of units, i.e., only one unit is used for each physical quantity. All units are based on decimal mathematics, and there are no conversion factors or constants to remember. The SI system (International System of Units) is a modernized version of the metric system in which certain less frequently used metric units have been eliminated.

2.1 BASIC UNITS

There are seven SI base units of measurement, six of which are used in design and construction and shown in the table below. (The seventh, the mole, is the amount of molecular substance and is used in chemistry and physics.)

Quantity	Unit	Symbol
length	meter	m
mass (weight)	kilogram	kg
time	second	s
electric current	ampere	A
temperature*	kelvin	K
luminous intensity	candela	cd

* Celsius temperature (°C) is more commonly used than kelvin (K), but both have the same temperature gradients. Celsius temperature is simply 273.15° warmer than kelvin, which begins at absolute zero. Kelvin is an SI unit while Celsius is not. However, **NJDOT will record temperatures in degrees Celsius (°C).**

One additional SI unit of interest is the plane angle unit of radians, which is sometimes used in various engineering calculations. However, **in surveying and construction, plane angles will be measured in degrees, minutes and seconds.**

2.2 DECIMAL PREFIXES

Many numbers resulting from metric calculations using the units shown above are too large or too small to be practically used. In design and construction three decimal prefixes are commonly used with the base units to produce manageable numbers. These are:

Prefix	Symbol	Order of Magnitude	Expression
mega	M	10^6	1 000 000 (one million)
kilo	k	10^3	1 000 (one thousand)
milli	m	10^{-3}	0.001 (one thousandth)

Decimal prefixes to the tertiary power of ten are preferred. The prefixes deci (d) for one tenth, centi (c) for one hundredth, deca (da) for ten, and hecto (h) for one hundred should not be used for linear measurement.

The prefixes giga (G) for one billion (10^9), micro (μ) for one millionth (10^{-6}), and nano (n) for one billionth (10^{-9}) are less common in engineering calculations. However, the prefix giga (G) is used for the modulus of elasticity of steel, and the prefix micro (μ) is used for sieve sizes under 1.00 mm. Also, "μ" and "n" are used in material specifications.

2.3 DERIVED UNITS

In addition to the basic metric units, there are numerous metric units which are derived from the basic units. Three derived units that are used frequently in structural design calculations are shown here:

Physical Property	Unit Name	Symbol	Expression
force	newton	N	$N = kg \cdot m/s^2$
pressure, stress	pascal	Pa	$Pa = N/m^2$
energy	joule	J	$J = N \cdot m$

2.3.1 Force

In order to perform metric calculations properly it is extremely important that the distinction between mass "kg" and force "N" be understood. When working in the "inch-pound" or "English" system, the quantities for "weight" and "mass" are interchangeable. In both systems, weight and force are used interchangeably. However, in the metric system there are separate units for mass "kg" and force "N". The familiar law of physics applies. Force N = mass x acceleration due to gravity. The metric acceleration due to gravity is 9.81 m/sec^2 (32.2 ft/sec^2 x 0.3048 m/ft). Mass "indicates the weight" of an object. The mass must be converted to force (by multiplying by 9.81) before computing structural reactions, shears, moments, or internal stresses.

NJDOT will use the word "weight" when measuring mass in kilograms or megagrams.

Consider the following examples:

- A block weighing 50 lb produces a force of 50 lb when placed on a beam. A block with a mass of 50 kg placed on a beam produces a force of 50 kg x 9.81 m/s^2 = 490 N.

- A simply supported beam 10 meters long with a mass of 200 kg/m would have a mass of 2 000 kg. However, the dead load of the beam used to calculate reactions, shears, moments, etc. would be 200 x 9.81 = 1 962 N/m.

The distinction between mass and force is very important in structural calculations. Conversion factors to convert directly from pounds to newtons are given in Section 2.5.

2.3.2 Stress

The pascal is not universally accepted as the only unit of stress. Because section properties are often expressed in millimeters, it is more convenient to express stress in a derivative of the pascal called the megapascal (MPa). (1 MPa = 1 N/mm^2)

2.3.3 Energy

Although the joule is a standard metric unit, it is not typically used in design. Moments are always expressed in terms of the derived units of N · m or kN · m.

2.4 SPECIAL UNITS

Some specialized units that may be of interest are as follows:

- The liter (L) is the measurement for the volume of liquids and gases.

  1 liter (L) = 1 000 milliliters (mL)
  1 000 liters (L) = 1 cubic meter (m^3)

- The hectare (ha) is a metric measurement used in surveying and right-of-way documents.

  1 hectare (ha) = 10 000 square meters (m^2)
  1 000 hectares (ha) = 10 000 square kilometers (km^2)

- The metric ton (t) is used to denote very large loads such as those used in excavation and earthwork.

  1 metric ton (t) = 1 000 kilograms (kg)
  1 metric ton (t) = 1 megagram (Mg)

NJDOT will use the term megagram (Mg) in lieu of metric ton (t).

2.5 METRIC CONVERSION FACTORS

The following table is intended to not only provide common conversion factors but to also illustrate typical equivalent conversion units between "English" and "metric" values. The factors will allow designers to get a feel for the magnitude of metric units as compared to English units. Use of the conversion factors may be necessary for computation purposes during the initial exposure to the metric system. However, it is hoped that the use of the conversion factors will quickly disappear as technical staff becomes familiar with and applies the metric system. For example, a conversion factor certainly would not be needed to compute metric areas or volumes when the plan dimensions are detailed in meters (or millimeters).

The unit "centimeter" should be avoided for linear measurement.

CONVERSION FACTORS

GENERAL				
Quantity	**From English Units**	**To Metric Units**	**Metric Symbol**	**Multiply By**
Length	inch foot foot foot (U.S. Survey) * yard mile	millimeter millimeter meter meter meter kilometer	mm mm m m m km	25.4 304.8 0.304 8 0.304 800 6 0.914 4 1.609 344
Area	square inch square foot square yard acre acre square mile	square millimeter square meter square meter square meter hectare square kilometer	mm^2 m^2 m^2 m^2 ha km^2	645.16 0.092 903 0.836 127 4 4 046.856 0.404 685 6 2.590 000
Volume	fluid ounce quart gallon gallon cubic inch cubic foot cubic yard acre-foot	milliliter liter liter cubic meter cubic millimeter cubic meter cubic meter cubic meter	ml L L m^3 mm^3 m^3 m^3 m^3	29.573 53 0.946 352 9 3.785 412 0.003 785 412 16 387.064 0.028 316 85 0.764 555 1 233.482
Temperature	degree Fahrenheit	degree Celcius	°C	5/9 (°F-32)
Velocity	feet per second miles per hour	meters per second kilometers per hour	m/s km/h	0.304 8 1.609 344
Rate of application	gallon per square foot gallon per square yard gallon per acre gallon per acre 1 000 gallons per acre	liter per square meter liter per square meter liter per hectare cubic meter per hectare cubic meter per hectare	L/m^2 L/m^2 L/ha m^3/ha m^3/ha	41.132 19 4.527 317 9.353 925 0.009 353 925 9.353 925
Slope	foot per foot foot per mile	meter per meter meter per meter	m/m m/m	1.0 0.000 189 4
Discharge	cubic foot per second	cubic meter per second	m^3/s	0.028 316 85

- Underlined factors in the table denote exact numbers.
- Use the number of digits needed for the required accuracy.
- When converting from metric units to English divide by the factor shown (multiply by the inverse).
- Conversion values based on 1 inch = 25.4 millimeters unless otherwise shown.
- * U.S. Survey Foot: In 1893, the U.S. foot was legally defined as 1200/3937 meters. In 1959, a refinement was made to bring the foot into agreement with the definition used in other countries, i.e., 0.304 8 meters. At the same time, it was decided that any data in feet derived from and published as a result of geodetic surveys within the U.S. would remain with the old standard, which is named the U.S. Survey foot. The new length is shorter by exactly two parts in a million.

CONVERSION FACTORS

CIVIL AND STRUCTURAL ENGINEERING				
Quantity	**From English Units**	**To Metric Units**	**Metric Symbol**	**Multiply By**
Mass	ounce pound ton (2,000 lb)	kilogram kilogram megagram	kg kg Mg	0.028 349 52 0.453 592 0.907 184
Mass per unit length	pound per inch pound per foot	kilogram per meter kilogram per meter	kg/m kg/m	17.857 97 1.488 16
Mass per unit area	pound per square foot ton (2,000 lb) per square foot	kilogram per square meter megagram per square meter	kg/m^2 Mg/m^2	4.882 43 9.764 856
Mass density	pound per cubic foot pound per cubic yard ton (2,000 lb) per cubic yard	kilogram per cubic meter kilogram per cubic meter megragram per cubic meter	kg/m^3 kg/m^3 Mg/m^3	16.018 46 0.593 276 1.186 554
Force	pound kip ton (2,000 lb)	newton kilonewton kilonewton	N kN kN	4.448 222 4.448 222 8.896 444
Force per unit length	pound per inch pound per foot kip per foot ton (2,000 lb) per foot	newton per meter newton per meter kilonewton per meter kilonewton per meter	N/m N/m kN/m kN/m	175.126 8 14.593 90 14.593 90 28.187 80
Force per unit area, pressure, stress, modulus of elasticity	pound per square inch kip per square inch kips per square inch pound per square foot kip per square foot	kilopascal megapascal gigapascal kilopascal megapascal	kPa MPa GPa kPa MPa	6.894 757 6.894 757 0.006 894 757 0.047 880 26 0.047 880 26
Bending moment, torque, moment of force	pound inch pound foot	newton meter newton meter	$N \cdot m$ $N \cdot m$	0.112 984 8 1.355 818
Moment of mass	pound foot	kilogram meter	$kg \cdot m$	0.138 255
Moment of inertia	inch to the fourth power	millimeter to the fourth power	mm^4	416 231.
Section modulus	inch cubed	millimeter cubed	mm^3	16 387.064

- Underlined factors in the table denote exact numbers.
- Use the number of digits needed for the required accuracy.
- When converting from metric units to English divide by the factor shown (multiply by the inverse).
- Conversion values based on 1 inch = 25.4 millimeters unless otherwise shown.

CONVERSION FACTORS

ELECTRICAL ENGINEERING			
From English Units	**To Metric Units**	**Metric Symbol**	**Multiply By**
abampere	ampere	A	10.
abcoulomb	coulomb	C	10.
abfarad	farad	F	10^{9}
abhenry	henry	H	10^{-9}
abmho	siemens	S	10^{9}
abohm	ohm	Ω	10^{-9}
abvolt	volt	V	10^{-8}
ampere hour	coulomb	C	3 600.
EMU of capacitance	farad	F	10^{9}
EMU of current	ampere	A	10.
EMU of electric potential	volt	V	10^{-8}
EMU of inductance	henry	H	10^{-9}
EMU of resistance	ohm	Ω	10^{-9}
ESU of capacitance	farad	F	$1.112\,650 \times 10^{-12}$
ESU of current	ampere	A	$3.335\,6 \times 10^{-10}$
ESU of electric potential	volt	V	299.79
ESU of inductance	henry	H	$8.987\,554 \times 10^{11}$
ESU of resistance	ohm	Ω	$8.987\,554 \times 10^{11}$
faraday (based on carbon-12)	coulomb	C	96 487.0
faraday (chemical)	coulomb	C	96 495.7
faraday (physical)	coulomb	C	96 521.9
footcandle	lux	lx	10.763 91
footlambert	candela per square meter	cd/m^2	3.426 259
gamma	tesla	T	10^{-9}
gauss	tesla	T	10^{-4}
gilbert	ampere	A	0.795 774 7
horsepower (electric)	watt	W	746.0
kilowatt hour	joule	J	3 600 000.
lumen per square foot	lumen per square meter	lm/m^2	10.763 91
maxwell	weber	Wb	10^{-8}
mho	siemens	S	1
oersted	ampere per meter	A/m	79.577 47
ohm centimeter	ohm meter	Ω · m	0.01
ohm circular-mil per foot	ohm meter	Ω · m	$1.662\,426 \times 10^{-9}$
statampere	ampere	A	$3.335\,640 \times 10^{-10}$
statcoulomb	coulomb	C	$3.335\,640 \times 10^{-10}$
statfarad	farad	F	$1.112\,650 \times 10^{-12}$
stathenry	henry	H	$8.987\,554 \times 10^{11}$
statmho	siemens	S	$1.112\,650 \times 10^{-12}$
statohm	ohm	Ω	$8.987\,554 \times 10^{11}$
statvolt	volt	V	299.792 5
unit pole	weber	Wb	$1.256\,637 \times 10^{-7}$

- Underlined factors in the table denote exact numbers.
- Use the number of digits needed for the required accuracy.
- When converting from metric units to English divide by the factor shown (multiply by the inverse).
- Conversion values based on 1 inch = 25.4 millimeters unless otherwise shown.

2.6 METRIC PROCEDURAL RULES

2.6.1 Rules for Pronunciation

Observe the following pronunciation conventions:

kilometer	accent the first syllable: **kill**-o-meter
pascal	rhymes with **rascal**
joule	rhymes with **pool**
hectare	accent the first syllable: **heck**-tare The second syllable rhymes with **care**
candela	accent the second syllable: can-**dell**-ah
siemens	sounds like seamen's

2.6.2 Rules for Writing Metric Symbols and Names

Observe the following rules when writing metric symbols and names:

- Print unit symbols in lower case except for liter (L), or unless the unit name is derived from a proper name (such as newton (N), pascal (Pa), degree Celsius (°C), or joule (J).
- Print decimal prefixes in lower case for magnitudes 10^3 and lower (i.e. k, m, μ and n) and print the prefixes in upper case for magnitudes 10^6 and higher (i.e. M and G).
- Print unit names in lower case (except Celsius), even those derived from a proper name (liter, joule).
- Leave a space between a numeral and a unit symbol (write 45 kg or 37 °C, not 45kg or 37°C or 37° C).
- Do not leave a space between a unit symbol and its decimal prefix (write kg, not k g).
- 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).
- Do not use a period after a symbol (write "12 g", not "12 g.") except when it occurs at the end of a sentence.
- Do not use a degree mark (°) with kelvin temperature (write K, not °K).
- Indicate the product of two or more units in symbolic form by using a dot positioned above the line (N · m or kg · m).
- Do not mix names and symbols (write N · m or newton meter, not N · meter or newton · m).

- For technical writing, use symbols in conjunction with numerals (the area is 10 m^2); write out unit names if numerals are not used (carpet is measured in square meters). Numerals may be combined with written unit names in nontechnical writing (10 meters). NJDOT will use both methods in its Standard Specifications.

2.6.3 Rules For Writing Numbers

Observe the following rules when writing numbers:

- Always use decimals, not fractions (write 0.75 g, not 3/4 g).

- Always use a zero before the decimal marker for values less than one (write 0.45 g, not .45 g).

- Use spaces to separate blocks of three digits for any number four digits and over. Never use commas to separate the blocks (write 12 345 kg or 0.123 45 kg). For plan dimensions, it will be satisfactory to omit or insert the space as desired:

  write 12 345.678 or 12345.678, but never 12,345.678

- The decimal marker is a period in the United States; in other countries, a comma is usually used.

- Stations are 1 kilometer units and should be shown as follows:

```
      34      +     567.89
      ↑               ↑
  kilometers       meters
```

2.6.4 Conversion and Rounding

Observe the following conventions when converting and rounding:

- When converting numbers from English units to metric units, generally round the metric value to the same number of significant figures as there were in the English number.

  Example:
  21 miles x 1.609 km/mile = 33.789 km, which rounds to 34 km

- Convert mixed English units (feet and inches, pounds and ounces) to the smaller English unit before converting to metric units and rounding.

  Example:
  5 feet, 3 inches = 63 inches
  63 inches x 25.4 mm/inch = 1 600.2 mm which rounds to 1 600 mm

For additional information concerning conversion and rounding of metric units, see the "Metric in Construction Newsletter" in Appendix A and Section 5 of ASTM E 380-93, "Standard Practice for Use of the International System of Units (SI)".

2.6.5 Soft and Hard Conversions

In a "soft" conversion, an English measurement is mathematically converted to its exact (or nearly exact) metric equivalent. In a "hard" conversion, a new rounded, rationalized metric equivalent is created that is convenient to work with and to remember.

Example of soft conversion:
48 inch diameter concrete culvert pipe
48 inches x 25.4 mm/inch = 1 219.2 mm, say 1 219 mm diameter

Example of hard conversion:
48 inch diameter concrete culvert pipe
48 inches x 25.4 mm/inch = 1 219.2 mm, say 1 200 mm diameter

Hard conversions to nominal metric dimensions should be used wherever possible.

2.6.6 Rules For Linear Measurement

Follow these rules for linear measurement:

- Use the meter and millimeter for design and construction. Do **not** use centimeter, decimeter, decameter, and hectometer.
- Use the kilometer for long distances and the micrometer for precision measurements.
- For surveying measurements, use the meter and the kilometer.

2.6.7 Rules For Area Measurement

Follow these rules for area measurement:

- The square meter is the preferred unit of measurement.
- Very large areas may be expressed in square kilometers and very small areas may be expressed in square millimeters.
- The hectare (10 000 square meters) should be used for land and water measurement only.
- Do **not** use the square centimeter, square decimeter, square decameter, or square hectometer.
- Linear dimensions such as 50 by 100 mm may be used. If so, indicate the width first and the height or length second.

2.6.8 Rules For Volume and Fluid Capacity Measurement

Follow these rules for volume and fluid capacity measurement:

- The cubic meter is the preferred unit of measurement for volumes in construction.

- The liter (L) and the milliliter (mL) may be used for fluid capacity (liquid or gaseous volume). (One liter = 1 000 mL, 1 000 L = 1 m^3).

2.6.9 Rules For Civil and Structural Engineering

The metric units most used in civil and structural engineering are:

- meter (m) - length
- kilogram (kg) - mass or weight
- second (s) - time
- newton (N) - force
- pascal (Pa) - pressure or stress

Follow these rules for civil and structural engineering:

- There are separate units for mass and force.
- The kilogram (kg) is the base unit for mass, which is the unit quantity of matter independent of gravity.
- The newton (N) is the derived unit for force (mass times acceleration, or kg · m/s^2). It replaces the unit "kilogram-force" (kgf), which should **not** be used.
- Do **not** use the joule to designate torque or moments. Torque or moments are always designated by the newton meter (N · m).
- The pascal (Pa) is the unit for pressure and stress (Pa = N/m^2).
- Structural calculations should be shown in MPa, kPa, or GPa.
- Plane angles in surveying will continue to be measured in degrees (either decimal degrees or degrees, minutes, and seconds) rather than the metric radian.
- Slope is expressed in nondimensional ratios. The vertical component is shown first and then the horizontal. For instance, a rise of one meter in four meters is expressed as 1:4. The units that are compared should be the same (meters to meters, millimeters to millimeters).
- For slopes less than 45°, the vertical component should be unitary (for example, 1:20). For slopes over 45°, the horizontal component should be unitary (for example, 5:1).

2.6.10 Rules Concerning the Use of Dual Units

Dual units (English and metric) should **not** be used except for right-of-way documents and for preliminary structural plans.

SECTION 3 - GUIDELINES FOR METRIC PLAN FORMAT

The following guidelines are intended to establish a standard format for metric plan sheets. These standards shall be followed whenever possible.

3.1 METRIC SCALES

Engineers have long been accustomed to reading either an engineer's scale or an architect's scale, with common scales such as 1" = 30' or 1/4" = 1'-0". These scales have probably become second nature to the engineer. However, the use of the engineer's metric scale may require a bit more thought and concentration, at least initially.

Metric scales are a ratio and are unitless. For example, instead of 1" = 30' or 1/4" = 1'-0", a metric scale will have a 1:50 ratio or a 1:300 ratio. This means that one of any unit on the plan sheet equals either 50 or 300 of the same units on the ground. (Note that the English scales mentioned here can also be converted to unitless ratios: 1" = 30' is 1:360 and 1/4" = 1'-0" is 1:48). To help in selecting the correct metric scale, a graphic bar scale shall be included on each plan sheet.

In order to produce metric drawings that are similar in size to current English drawings, the following scale substitutions are recommended:

EQUIVALENT ENGLISH AND METRIC SCALES		
ENGINEER SCALES		
English Scale	Recommended Metric Scale	% Enlargement or Reduction Using Metric Scale
1" = 5' (1:60)	1:50	+20
1" = 10' (1:120)	1:100	+20
1" = 20' (1:240)	1:250	-4
1" = 30' (1:360)	1:300	+20
1" = 40' (1:480)	1:500	-4
1" = 50' (1:600)	1:500	+20
1" = 60' (1:720)	1:600	+20
1" = 100' (1:1200)	1:1000	+20
1" = 200' (1:2400)	1:2000	+20
1" = 300' (1:3600)	1:3000	+20
1" = 400' (1:4800)	1:4000	+20
1" = 500' (1:6000)	1:5000	+20
1" = 600' (1:7200)	1:6000	+20
ARCHITECT SCALES		
3" = 1'-0" (1:4)	1:5	-20
1 ½" = 1'-0" (1:8)	1:10	-20
1" = 1'-0" (1:12)	1:10	+20
3/4" = 1'-0" (1:16)	1:20	-20
½" = 1'-0" (1:24)	1:25	-4
3/8" = 1'-0" (1:32)	1:30	+6.67
1/4" = 1'-0" (1:48)	1:50	-4
3/16" = 1'-0" (1:64)	1:50	+28
1/8" = 1'-0" (1:96)	1:100	-4
3/32" = 1'-0" (1:128)	1:125	+2.4
1/16" = 1'-0" (1:192)	1:200	-4
1/32" = 1'-0" (1:384)	1:400	-4

Note: The preferred scale for roadway construction drawings is 1:300.

3.2 METRIC PLAN SHEET SIZE

The International Organization for Standardization (ISO) has adopted the "A" series of drawings as the preferred metric drawings sizes. There are five "A" series sizes":

ISO Designation	Metric Sheet Size	Equivalent English Sheet Size	Replaces
A0	841 by 1189 mm	33.1 by 46.8 inches	34 by 44 inches
A1	594 by 841 mm	23.4 by 33.1 inches	22 by 34 inches
A2	420 by 594 mm	16.5 by 23.4 inches	17 by 22 inches
A3	297 by 420 mm	11.7 by 16.5 inches	11 by 17 inches
A4	210 by 297 mm	8.3 by 11.7 inches	8½ by 11 inches

The "A0" base drawing has a drawing area of one square meter. Smaller sheet sizes are obtained by halving the long dimension of the previous size. All "A" series drawings have a height to width ratio of one to the square root of 2.

All plan sheets will conform to the "A1" metric sheet size. The overall sheet dimensions are 841 mm wide and 594 mm high. A border of 15 mm shall be used on the bottom and right side of all plan sheets (see attached sketch of proposed metric sheet layout in Appendix B). Until such time at which metric paper is commonly available, drawings must be laid out such that they will fit on a working area of 775 by 540 mm as shown.

Reduced (half-size) drawings will be printed on "A3" paper.

3.3 METRIC DIMENSIONING

Meters and millimeters shall be the only dimensions allowed on metric plan sheets. Distances currently labeled in feet or feet and inches shall be labeled in meters or decimals of a meter, using the correct meter designation "m". Smaller dimensions, such as curb heights, pavement thicknesses, and bridge details, that are currently labeled in inches shall be labeled in millimeters using the correct millimeter designation "mm".

A space shall be used instead of a comma to separate groups of three digits. For example, 1,000.00 will be shown as 1 000.00. A note shall be prominently added to each metric drawing stating: **"All dimensions shown on this sheet are in metric units."**

3.4 CADD METRIC WORKING UNITS

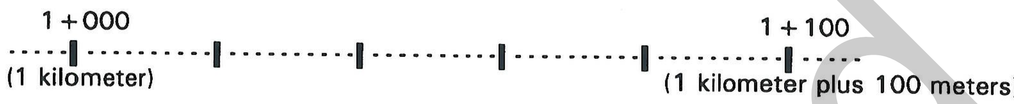
The NJDOT CADD Users Group has decided to choose a universal working unit for design files in Microstation (MU:SU:PU) of 1:1 000:10 and the dialog box will be depicted as follows:

Unit Names	Master Units	m
	Sub-units	mm
Resolutions	1 000 mm per m	
	10 positional units per mm	
Working Area	429 496 m^2	

SECTION 4 - ROADWAY PLAN PREPARATION GUIDELINES

4.1 STATIONING

A metric stationing concept based on one kilometer will be used. For example, Station 12+345.67 indicates a point 345.67 meters forward of Station 12+000. Plans will show intermediate ticks every 20 meters with every fifth tick mark labeled (i.e., every 100 meter tick mark is labeled).



All match marks on plan sheets will be noted with the full metric station number for that point.

An equivalent conversion from English units to metric units will be used by survey parties when re-establishing points from a previously run survey. The kilometer stationing on existing roadway alignments shall be created by converting the milepost nearest to the project to kilometers. For example, a rehabilitation project on an existing highway near Milepost 50.0 on that highway would be converted as follows:

$$50.0 \text{ miles} \cdot 1.609\,344 \text{ km/mile} = 80.467\,2 \text{ km}$$

Therefore, the station at Milepost 50.0 would be kilometer Station 80+467.2.

For new alignments, the kilometer stationing is arbitrary but should never begin with 0+000 in order to provide for back stationing should the project be extended.

4.2 CROSS SECTIONS

Cross sections shall be taken every 20 meters (about 65 feet). A larger interval may be considered when uniform templates are used over flat terrain. Additional cross sections should be provided to reflect abrupt changes in either the template or the existing ground, or as deemed necessary to accurately describe existing conditions.

Cross section elevations (on the vertical scale) shall be labeled every 2 meters, and distances (on the horizontal scale) shall be labeled every 10 or 20 meters, depending on the scale used.

Cross section grids:

English Scale	Recommended Metric Scale
1" = 5' vertical	1:50 vertical
1" = 5' horizontal	1:50 horizontal
1" = 10' vertical	1:100 vertical
1" = 10' horizontal	1:100 horizontal

4.3 PROFILES

Profile elevations shall be labeled every one meter where a vertical scale is used. The horizontal distance grid shall be drawn every 20 meters (the same as the cross section interval) and shall have labeled station tick marks every 100 meters (the same as shown on the alignment).

Profile Grids:

English Scale	Recommended Metric Scale
1" = 5′ vertical	1:50 vertical
1" = 50′ horizontal	1:500 horizontal

Example: For a working profile scale of 1" = 2′ vertical and 1" = 20′ horizontal, a 1:20 metric scale vertical and a 1:200 metric scale horizontal can be used. This allows the engineer to use the same 1:200 scale for both measurements by just dividing by 100 to get the 1:20 scale.

4.4 SLOPES

Slopes which are now written "horizontal:vertical" shall be written "vertical:horizontal" in accordance with current AASHTO guidelines. For example, a 4:1 slope will now be written as 1:4.

4.5 ANGLES AND HORIZONTAL CURVES

Angular measurements will continue to be expressed in degrees, minutes, and seconds. However, a radius definition of horizontal curves will be used rather than the degree of curve currently used (since there is no longer a 100 foot station by which to define degree of curvature). For example, a 3° horizontal curve on a new alignment would be referred to as a 580 m radius curve (radius of a 3° curve = 1909.86′ or 582.126 m).

Metric radii of horizontal curves on new alignments should always be expressed in multiples of 5 meter increments. On the other hand, alignments which incorporate a previously defined horizontal curve should continue to express the radius to the closest 0.001 m. If the 3° curve noted above is a recreation of a previously established curve, it would be assigned a 582.126 meter radius.

Three cases defining horizontal curves are shown below. In all three cases, the curve starts at P.C. Sta. 300 + 59.41 (English units) equivalent to P.C. Sta. 9 + 162.108 (metric units, kilometer stationing).

Case A: Normal English unit curve definition.

Case B: Metric definition assuming that Case A curve data defined the roadway centerline from a previous survey and is to be retained. All curve data is a direct (soft) conversion from English to metric.

Case C: Metric definition of a paper relocation starting at P.C. Sta. 9 + 162.108 (kilometer stationing) having approximately the same curvature as the Case A curve. Note that the radius is given in a 5 meter increment.

Case A	Case B	Case C
P.I. Sta. 302+67.75	P.I. Sta. 9+225.609	P.I. Sta. 9+225.376
Δ = 12°30′	(Δ = 12°30′)	(Δ = 12°30′)
D=3°00′		
T=209.16′	T=63.752 m	T=63.520 m
L=416.67′	L=127.001 m	L=126.535 m
R=1909.86′	R=582.126 m	R=580 m
E=11.42′	E=3.481 m	E=3.468 m

Presentation of information for spiral curves will be in a similar manner.

4.6 ELEVATIONS AND CONTOUR INTERVALS

Benchmark elevations will be converted directly from feet to meters. A benchmark elevation of 115.56 feet will be converted to 35.223 meters (115.56 ft x 0.304 8 m/ft = 35.223m). Benchmark elevations will be shown to a 0.001 meter accuracy.

When contours are shown on drawings, the contour interval will be 0.5 meters or 1.0 meters, depending on the scale, the terrain, and the need for more or less definition. Each fourth contour will represent a whole meter elevation (105.0, 107.0, etc.) and shall be emphasized and annotated as an index contour. Intermediate contours will not be annotated unless they represent a high or low contour on the ground surface that cannot be determined by interpolation between adjacent full meter contours, and will be noted to the nearest 0.01 m.

In rugged terrain or on steep slopes, the contour density may interfere with readability. When this occurs, the intermediate contours shall be removed from the densely packed areas only. The index contours shall be retained in these areas.

4.7 SURVEY PLOTTING ACCURACY

As a frame of reference, distances expressed in metric units will have the following accuracy in English units:

Closest 0.1 meters will be within 0.17′ of the true distance.
Closest 0.01 meters will be within 0.015′ of the true distance.
Closest 0.001 meters will be within 0.0013′ of the true distance.

With this in mind, survey distances and elevations transferred to plan sheets should be shown as follows:

- Horizontal alignment data (curve information, equations, reference point tie-ins, etc.), section corner tie-ins, and benchmark elevations shall be shown to the closest 0.001 meters.

- Roadway elevations, used for pavement tie-ins and vertical clearance computations, shall be shown to the closest 0.005 meters.

- All horizontal pluses, offsets, physical feature dimensions and locations, etc. may be shown to either the closest 0.1 or 0.01 meters. As a general rule, the closest 0.01 meters accuracy is preferred.

4.8 PROPOSED FEATURES ON PLANS

The location of all proposed features shall be given in meters or fractional parts of meters to the following accuracy:

- All proposed horizontal alignment data shall be given to an accuracy of 0.001 meters. Metric curve radii shall be in 5 meter increments.

- It is suggested that vertical profile alignment data be shown with P.V.I. Stations at even 10 m stations, vertical curve lengths in 20 m increments, and P.V.I. Elevations given to 0.001 meter accuracy, where practical. All other vertical elevations, breaks in ditch grades, pipe invert elevations, etc. should be shown to the closest 0.01 meters.

- The location of all proposed features shall be shown to the closest 0.3 meters, where practical, and rarely closer than 0.1 meter.

Some manufactured items do not yet have a standard metric size, and these items shall be converted to metric sizes using a soft conversion. (When industry has converted their items to a nominal metric equivalent, then those new dimensions shall be used.) If the item is nominally dimensioned in feet, convert to meters. If the item is nominally dimensioned in inches, convert to millimeters.

4.8.1 Drainage Pipe Sizes

Drainage pipe sizes will be shown on roadway plans using the standard diameters contained in the respective AASHTO Metric Specification (M series) for that particular type of pipe. Currently approved AASHTO metric pipe specifications are listed below:

M 36/M36M Corrugated Steel Pipe, Metallic Coated, for Sewers and Drains.

M 86M Concrete Sewer, Storm Drain, and Culvert Pipe (Metric).

M 167/M167M Corrugated Steel Structural Plate, Zinc Coated, for Field Bolted Pipe, Pipe Arches, and Arches.

M 170M Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe (Metric).

M 175M Perforated Concrete Pipe (Metric).

M 176M Porous Concrete Pipe (Metric).

M 178M Concrete Drain Tile (Metric).

M 196/M196M Corrugated Aluminum Pipe for Sewers and Drains.

M 199M Precast Reinforced Concrete Manhole Sections (Metric).

M 206M Reinforced Concrete Arch Culvert Storm Drain and Sewer Pipe (Metric).

M 207M Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe (Metric).

M 219/M219M Corrugated Aluminum Alloy Structural Plate for Field-bolted Pipe, Pipe Arches and Arches.

M 242M Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe (Metric).

M245/M245M Corrugated Steel Pipe, Polymer Precoated for Sewer and Drains.

M 259M Precast Reinforced Concrete Box Sections for Culverts, Storm Drains and Sewers (Metric).

M 273M Precast Reinforced Concrete Box Sections for Culverts, Storm Drains and Sewers with less than 0.6 m of Cover Subject to Highway Loadings (Metric).

M 304M Poly(Vinyl Chloride) (PVC) Ribbed Drain Pipe and Fittings Based on Controlled Inside Diameter.

Pipe required for construction but not covered by one of the above listed specifications shall be sized based on a soft conversion rounded to the nearest full millimeter.

The following table contains the hard converted sizes of corrugated metal and reinforced concrete pipes as listed in the AASHTO Specifications. Consult individual material specifications for metric sizes not shown, such as arches, elliptical pipe, and PVC pipe. Individual material specifications also contain complete information on CMP steel sheet thicknesses, height and spacing of corrugations, wall thickness, reinforcing size, etc.

CIRCULAR PIPE DIMENSION GUIDE			
English Unit Size (inches)	Soft Converted Metric Size (mm)	AASHTO Nominal Metric Size (mm)	
		CMP	RCP
4	102 (101.6)	100	--
6	152 (152.4)	150	--
8	203 (203.2)	200	--
10	254 (254.0)	250	--
12	305 (304.8)	300	300
15	381 (381.0)	400	375
18	457 (457.2)	450	450
21	533 (533.4)	500	525
24	610 (609.6)	600	600
27	686 (685.8)	700	675
30	762 (762.0)	800	750
33	838 (838.2)	--	825
36	914 (914.4)	900	900
42	1 067 (1 066.8)	1 000	1 050
48	1 219 (1 219.2)	1 200	1 200
54	1 372 (1 371.6)	1 400	1 350
60	1 524 (1 524.0)	1 500	1 500
66	1 676 (1 676.4)	--	1 650
72	1 829 (1 828.8)	1 800	1 800
78	1 981 (1 981.2)	2 000	1 950
84	2 134 (2 133.6)	2 200	2 100
90	2 286 (2 286.0)	--	2 250
96	2 438 (2 438.4)	2 400	2 400
102	2 591 (2 590.8)	--	2 550
108	2 743 (2 743.2)	2 700	2 700
114	2 896 (2 895.6)	--	2 850
120	3 048 (3 048.0)	3 000	3 000
126	3 200 (3 200.4)	--	3 150
132	3 353 (3 352.8)	3 300	3 300
138	3 505 (3 505.2)	--	3 450
144	3 658 (3 657.6)	3 600	3 600

Note: Parentheses show exact conversion to millimeter

4.8.2 Box Culvert Sizes

Concrete box sizes will be in increments of 300 mm, which is a difference of 1.6% from the 1 foot increments used in English units and within construction tolerances. The following table contains the hard converted sizes of concrete boxes in accordance with AASHTO metric specifications for box culverts. Note that although culverts are nominally dimensioned in feet in English units, they will be nominally dimensioned in millimeters in metric units.

BOX CULVERT DIMENSION GUIDE		
English Unit Size (feet)	**Soft Converted Metric Size (mm)**	**AASHTO Nominal Metric Size (mm)**
2	610 (609.6)	600
3	914 (914.4)	900
4	1 200 (1 219.2)	1 200
5	1 520 (1 524.0)	1 500
6	1 830 (1 828.8)	1 800
7	2 130 (2 133.6)	2 100
8	2 440 (2 438.4)	2 400
9	2 740 (2 743.2)	2 700
10	3 050 (3 048.0)	3 000

Note: Parentheses show exact conversion to millimeter

4.8.3 Steel Beam Guide Rails

Steel beam guide rails and their accessories must be soft converted until such time the industry makes a hard conversion. AASHTO Material Specification M 180 contains four figures showing typical soft conversion dimensions. These dimensions should be used for preparation of contract plans.

4.8.4 Utilities

The location and size of all existing and proposed utility facilities must be shown on the plans in metric units (e.g., the distance from the traveled way, clearance above the ground, depth of burial, size of utility pipe, etc.). Existing facilities shall be located and described using soft converted metric units from the English measurements. Proposed facilities shall be located using metric dimensions and described using hard metric materials when available.

4.9 TYPICAL CROSS SECTION ELEMENTS

AASHTO has already recommended many of the standard metric lane and shoulder widths. These values are in 0.1 m width increments and are generally narrower than current widths. Widths of other cross section elements should also be established in 0.1 m increments. The resulting roadway width (edge of shoulder to edge of shoulder) then will always be in increments of 0.1 meters.

WIDTH OF CROSS SECTION ELEMENTS			
LANES		**SHOULDERS**	
English Width (ft)	**Metric Width (m)**	**English Width (ft)**	**Metric Width (m)**
10	3.0 (=9.84′)	2	0.6 (=1.97′)
11	3.3 (=10.83′)	4	1.2 (=3.94′)
12	3.6 (=11.81′)	6	1.8 (=5.91′)
14	4.2 (=13.78′)	8	2.4 (=7.87′)
16	4.8 (=15.75′)	10	3.0 (=9.84′)

Note: Underlined values have been recommended by AASHTO

All other typical cross section elements (concrete pavement thickness, aggregate or subbase depth, special subgrade treatment depths, underdrain dimensions, etc.) shall be shown in millimeters. The equivalent metric dimensions will be the current thickness in inches multiplied by 25 mm. For example, ten inch concrete pavement shall be shown as 250 mm; 24 inches of subgrade treatment shall be shown as 600 mm; a six inch depth of aggregate shall be shown as 150 mm; a four inch arch shall be shown as 100 mm; etc.

Slope is expressed in nondimensional ratios. The vertical component is shown first and then the horizontal. For instance, a rise of one meter in four meters is expressed as 1:4. The units that are compared should be the same (meters to meters, millimeters to millimeters). For slopes less than 45 degrees, the vertical component should be unitary (for example, 1:20). For slopes over 45 degrees, the horizontal component should be unitary (for example 5:1).

Cross-slopes on pavements and shoulders are to be expressed in a dimensionless, vertical-to-horizontal ratios, in percent form. A comparison of currently used slopes to the recommended decimal equivalent is as follows:

COMPARISON OF SLOPE RATES	
English	**Recommended Metric**
1/8" Per Ft.	0.01 or 1%
3/16" Per Ft.	0.016 or 1.6%
1/4" Per Ft.	0.02 or 2%
3/8" Per Ft.	0.03 or 3%
1/2" Per Ft.	0.04 or 4%
3/4" Per Ft.	0.06 or 6%
1" Per Ft.	0.08 or 8%

4.10 DESIGN SPEEDS

AASHTO has adopted the following metric design speeds:

AASHTO-ADOPTED METRIC DESIGN SPEED VALUES	
English Value (mph)	**Metric Equivalent (km/h)**
20	30 (= 18.6 mph)
25	40 (= 24.9 mph)
30	50 (= 31.1 mph)
35 and 40	60 (= 37.3 mph)
45	70 (= 43.5 mph)
50	80 (= 49.7 mph)
55	90 (= 55.9 mph)
60 and 65	100 (= 62.1 mph)
70	110 (= 68.4 mph)
75	120 (= 74.5 mph)

4.11 VERTICAL CLEARANCE

Minimum vertical clearances will be maintained as follows:

	Metric	English
Freeways, Expressways and Major Arterials (NHS)	5.1 m (16.73 ft.)	16 ft. 6 in.
Minor Arterials, Collectors and Local Roads	4.8 m (15.75 ft.)	15 ft. 6 in.
Railroads	7.0 m (22.97 ft.)	23 ft. 0 in.

Additional clearance should be provided where economically feasible. Existing clearances which will be maintained shall be soft-converted.

SECTION 5 - BRIDGE PLAN PREPARATION GUIDELINES

Until metrication of all NJDOT Standards has been completed and as per the May 10, 1994 All Design Units Memorandum (94014 ADU), the following general statements apply to bridge and structural design:

- Design calculations for bridges and structures shall be performed in English units. This practice follows the 1992 AASHTO Standard Specifications for Highway Bridges and the current edition of the NJDOT Design Manual for Bridges and Structures, as both documents use the English system. Specific design guidance will be given in the future metric edition of the NJDOT Design Manual for Bridges and Structures.

- Bridges and structures shall be designed using construction materials based on the English system. All construction materials based on English units shall be soft converted to metric units on bridge construction plans and in the specifications. Bridge phase review plans shall use dual units, English and metric for Phase 1, 2 and 3 bridge plans. However, final bridge plans shall contain metric units only. Specific guidance concerning the use of metric size construction materials, including hard conversions, will be addressed in the future metric edition of the NJDOT Design Manual for Bridges and Structures and in the future metric edition of the NJDOT Standard Specifications for Road and Bridge Construction.

Until the metrication process is complete, the following information may be used for guidance.

5.1 PLAN DIMENSIONS

As discussed in Section 3.3, meters and millimeters shall be the only dimensions allowed on metric bridge plan sheets. No fractions shall be used. Large distances currently labeled in feet or feet and inches shall be labeled in meters or decimals of a meter using the correct meter designation "m". Small dimensions currently labeled in inches or fractions of inches shall be labeled in millimeters using the correct millimeter designation "mm".

Elevations shall be shown in meters to three decimal places and will be noted as "El. 210.130". Note that the meter designation "m" is not used for elevations. All stationing shall be shown in kilometers (as discussed in Section 4.1), all angles shall be shown in degrees, minutes and seconds, and all slopes shown on bridge plans shall be shown in percent.

A note shall be prominently added to each bridge drawing stating:

"All dimensions shown on this sheet are in metric units".

5.2 HARD AND SOFT CONVERSIONS

Soft conversions shall be used, in general, on some manufactured items such as expansion joints, floor drains, standard elastomeric bearings, steel pile shells, etc. Hard conversions shall be used for most concrete dimensions of formed members, beam spacing, pile spacing, reinforcing spacing, etc. One exception should be noted: round column members which are formed using standard diameter metal forms and the thickness of walls and caps formed with round ends shall continue to be expressed in millimeters using a soft conversion.

Hard conversion of concrete dimensions should be rational, rounded dimensions which are convenient to work with and easy for field personnel to measure. Many dimensions can be established in increments of 100 mm (span lengths, beam spacing, pier heights, etc.). Where 100 mm increments are not possible, the use of 50 mm and 10 mm increments is encouraged. A listing of suggested conversion units is included in Appendix C. Although the list is not complete, it will provide an indication of the type of conversion (hard or soft) and recommended metric conversion values.

For additional information relative to the metric conversion of bridge-related items, see Appendix D.

SECTION 6 - RIGHT OF WAY PLAN PREPARATION GUIDELINES

Since a final decision on metric conversion for right-of-way (ROW) plans and property deeds has not been made by the Federal Highway Administration (FHWA), **dual units will be used on all ROW plans and deeds.** It is suggested that metric units be shown first, followed by the English equivalent in parentheses.

Scales, stationing, and angular measurements shall follow those rules previously established in Sections 3 and 4. Property lines will be shown in standard "metes and bounds" using dual metric and English units. Metric distances will be to the nearest 0.001 meter. It is suggested that, for all dimensions on ROW plans of interest to the public, metric distances spell out the word "meters" instead of using the abbreviation "m" to help the general public become familiar with the new system. Similarly, areas should be designated with the words "square meters" or "hectares" rather than the abbreviations "m^2" or "ha".

Examples: N 22° 15′ 30" E 238.145 meters (781.31 ft)
Lot Area: 2.235 hectares (5.52 acres)

SECTION 7 - TRAFFIC CONTROL PLAN PREPARATION GUIDELINES

The Federal mandate for metric conversion of construction plans will affect taper lengths, tangent lengths, traffic control device spacings, pavement marking patterns, sign design, and sign panel sizes.

7.1 SIGNING

Regulatory and advisory speed limits, distance messages, milepost markers, and reference markers will remain in English units until conversions are directed by the FHWA.

7.2 MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES (MUTCD)

The Manual on Uniform Traffic Control Devices (MUTCD) is not expected to be released in metric format until 1996. Therefore, interim guidance for signs, markings, traffic control devices, and traffic control plans will be developed, as required, through the current Metrication of NJDOT Standards project.

7.3 STANDARD METRIC SIZES

- **Sign Panel Sizes** - The length and width dimensions for the sign panels will be converted using a conversion factor of 1 inch to 25 mm. Typical standard sizes will be 300 mm (12"), 450 mm (18"), 600 mm (24"), 750 mm (30"), etc.

- **Sign Text** - All vertical dimensions of the sign message will be converted using the factor of 1 inch to 25 mm (example: typical letter heights will be 100 mm [4 inch], 200 mm [8 inch], etc.). All horizontal text dimensions will be converted using the factors of 1 inch to 25 mm (example: stroke width, spacing, etc.). For additional information, refer to "1977 Standard Alphabets for Highway Signs and Pavement Markings (Metric Edition)", U.S. Department of Transportation, Federal Highway Administration Office of Traffic Operations.

- **Traffic Control** - The taper lengths, tangent lengths, and traffic control device spacings will be converted using the factor of 1 foot to 0.3 m, until more specific guidance is received from the FHWA. The distances and advisory speed limits on construction signs will remain in English units until required otherwise by the FHWA.

- **Pavement Markings** - The 4 inch stripe will convert to a 100 mm stripe. The 10 foot stripe with 30 foot gap will convert to a 3 m stripe with a 9 m gap.

- **Electrical Conductor and Conduit Sizes** - Wire sizes will remain in English units. The National Electrical Code (NEC) does not yet have provisions for converting conduit sizes, and these dimensions are nominal trade sizes. Therefore, conduit sizes shall be soft-converted to metric units.

- **Fabrication Details** - Unless an individual manufacturer specified for your project has hard-converted materials, these details will be soft converted to metric units.

7.4 MAINTENANCE AND PROTECTION OF TRAFFIC

Maintenance and protection of traffic shall continue to follow current practices and ratios expressed in metric units and rounded as necessary. Distances and taper lengths shall be rounded up to the nearest meter or 10 meters, as appropriate. For example, a taper length of 660 feet shall become 200 meters. Cones which were spaced 55 feet apart will be spaced at 17 meters.

Metric in Construction

Volume 3, Issue 4

July-August 1994

CONVERSION AND ROUNDING

The conversion of inch-pound units to metric is an important part of the metrication process. But conversion can seem deceptively simple because most measurements have implied, not expressed, tolerances and many products (like 2-by-4s) are designated in rounded, easy-to-remember "nominal" sizes, not actual ones. People working in a particular profession or trade gain an intuitive feel for the allowable tolerances of the measurements and products they use and learn the difference between nominal and actual sizes. It is this knowledge that must be relied upon when converting to metric.

For instance, if anchor bolts are to be imbedded in masonry to a depth of 8 inches, what should this depth be in millimeters? A strict conversion (using 1 inch = 25.4 mm) results in an exact dimension of 203.2 mm. But this implies an accuracy of 0.1 mm (1/254 inch) and a tolerance of ± 0.05 mm (1/508 inch), far beyond any reasonable measure for field use. Similarly, 203 mm is overly precise, implying an accuracy of 1 mm (about 1/25 inch) and a tolerance of ± 0.5 mm (about 1/50 inch). As a practical matter, ± 3 mm (1/8 inch) is well within the tolerance for setting anchor bolts. Applying ± 3 mm to 203.2 mm, the converted dimension should be in the range of 200 mm to 206 mm. Metric measuring devices emphasize 10 mm increments and masons work on a 200 mm module, so the selection of 200 mm would be a convenient dimension for masons to use in the field. Thus, a reasonable metric conversion for 8 inches, ***in this case***, is 200 mm.

This example may sound complicated but in fact we mentally round to easy-to-use numbers all the time and think nothing of it. What the example does illustrate is the need for experience, common sense, and consideration of how measures are used. Much has been written about conversion but the basic points to remember are these:

- Conversion should be performed by experienced professionals, not by clerical staff with calculators. Automated conversion programs should be used with care.
- Understand the allowable tolerances for the measurements you are converting.
- Always convert with the end application or use in mind. Remember that dimensional tolerances at the work site are rarely less than a few millimeters so it is easiest for field personnel to measure in 10 mm or 5 mm increments.
- The most common conversion error is under-rounding, which implies a level of precision that is not inherent in the inch-pound number. If your linear conversions are accurate to 0.1 mm or even 1 mm, you are probably doing them incorrectly; any dimension over a few inches usually can be rounded to the nearest 5 mm (1/5 inch) and anything over a few feet to the nearest 10 mm (2/5 inch)--or more.

  For example, the NFPA *Life Safety Code* rounds dimensions under 30 inches to the

Continued on page 4

[redacted]

Metric in Construction is the newsletter of the Construction Metrication Council of the National Institute of Building Sciences, Washington, D.C. Reproduction and distribution of its contents is encouraged provided the Council receives attribution. Copies of previous newsletters are available upon request.

CONSTRUCTION METRICATION COUNCIL
National Institute of Building Sciences
1201 L Street, N.W., Suite 400
Washington, D.C. 20005
Telephone 202-289-7800; Fax 202-289-1092

Metric in Construction is a bimonthly newsletter published by the Construction Metrication Council to inform the building community about metrication in U.S. construction. The Construction Metrication Council was created by the National Institute of Building Sciences to provide industry-wide, public and private sector support for the metrication of federal construction and to promote the adoption and use of the metric system of measurement as a means of increasing the international competitiveness, productivity, and quality of the U.S. construction industry.

The National Institute of Building Sciences is a nonprofit, nongovernmental organization authorized by Congress to serve as an authoritative source on issues of building science and technology.

The Council is an outgrowth of the Construction Subcommittee of the Metrication Operating Committee of the federal Interagency Council on Metric Policy. The Construction Subcommittee was formed in 1988 to further the objectives of the 1975 *Metric Conversion Act*, as amended by the 1988 *Omnibus Trade and Competitiveness Act*. To foster effective private sector participation, the activities of the subcommittee were transferred to the Council in April 1992.

Membership in the Council is open to all public and private organizations and individuals with a substantial interest in and commitment to the Council's purposes. The Council meets bimonthly in Washington, D.C.; publishes the *Metric Guide for Federal Construction* and this bimonthly newsletter, and coordinates a variety of industry metrication task groups. It is funded primarily by contributions from federal agencies. For membership information, call the Council at the above phone number.

ROUNDING TABLE, 1/32 INCH TO 4 INCHES

Underline denotes exact conversion
Shaded figures are too exact for most uses

Inches	Nearest 0.1 mm (1/254")	Nearest 1 mm (1/25")	Nearest 5 mm (1/5")
1/32"	0.8	1	
1/16"	1.6	2	
3/32"	2.4	2	
1/8"	3.2	3	
3/16"	4.8	5	
1/4"	6.4	6	
5/16"	7.9	8	
3/8"	9.5	10	
7/16"	11.1	11	
1/2"	12.7	13	
9/16"	14.3	14	
5/8"	15.9	16	
3/4"	19.0	19	
7/8"	22.2	22	
1"	25.4	25	25
1-1/4"	31.8	32	30
1-1/2"	38.1	38	40
1-3/4"	44.4	44	45
2"	50.8	51	50
2-1/4"	57.2	57	55
2-1/2"	63.5	64	65
2-3/4"	69.8	70	70
3"	76.2	76	75
3-1/4"	82.6	83	85
3-1/2"	88.9	89	90
3-3/4"	95.2	95	95
4"	101.6	102	100

ROUNDING TABLE, 4 INCHES TO 100 FEET

Underline denotes exact conversion
Shaded figures are too exact for most uses

Inches and Feet	Nearest 0.1 mm (1/254")	Nearest 1 mm (1/25")	Nearest 5 mm (1/5")	Nearest 10 mm (2/5")	Nearest 50 mm (2")	Nearest 100 mm (4")	1" = 25 mm exactly
4"	101.6	102	100	100			100
5"	127	127	125	130			125
6"	152.4	152	150	150			150
7"	177.8	178	180	180			175
8"	203.2	203	205	200			200
9"	228.6	229	230	230			225
10"	254	254	255	250			250
11"	279.4	279	280	280			275
1-0"	304.8	305	305	300	300		300
2-0"	609.6	610	610	610	600		600
3'-0"	914.4	914	915	910	900		900
4'-0"	1219.2	1219	1220	1220	1200		1200
5'-0"		1524	1525	1520	1500		1500
6'-0"		1829	1830	1830	1850		1800
7'-0"		2134	2135	2130	2150		2100
8'-0"		2438	2440	2440	2450		2400
9'-0"		2743	2745	2740	2750		2700
10'-0"		3048	3050	3050	3050	3000	3000
15'-0"		4572	4570	4570	4550	4600	4500
20'-0"		6096	6095	6100	6100	6100	6000
25'-0'		7620	7620	7620	7600	7600	7500
30'-0"		9144	9145	9140	9150	9100	9000
40'-0"		12 192	12 190	12 190	12 200	12 200	12 000
50'-0"		15 240	15 240	15 240	15 250	15 200	15 000
75'-0"		22 860	22 860	22 860	22 850	22 900	22 500
100'-0"		30 480	30 480	30 480	30 500	30 500	30 000

nearest millimeter, from 30 inches to 10 feet to the nearest 10 mm, from 10 to 50 feet to the nearest 100 mm, and over 100 feet to the nearest meter. Accessibility standards uniformly round dimensions under 1/2 inch to the nearest 0.5 mm, from 1/2 inch to 2 feet to the nearest millimeter, from 2 to 40 feet to the nearest 5 mm, and over 40 feet to the nearest meter. ASTM standards vary in their rounding practices depending on the subject involved, but many use the rounded conversion factor 1 inch = 25 mm.

- Practice helps. With a little practice, you will begin to get the "feel" for conversion and gain confidence and speed.

Since most construction measurements are linear, rounding tables for commonly used dimensions are provided on the inside pages of this newsletter.

For in-depth guidance on metric conversion and rounding, see ANSI/IEEE 268, *American National Standard for Metric Practice*, Appendix C [American National Standards Institute, phone 212-642-4900] and ASTM E 380, *Standard Practice for Use of the International System of Units (SI)*, Section 5 [American Society of Testing and Materials, phone 215-299-5585]. A very readable discussion on conversion and rounding is included in Stan Jakuba's *Metric (SI) in Everyday Science and Engineering*, Chapter 6 [Society of Automotive Engineers, phone 412-776-4841].

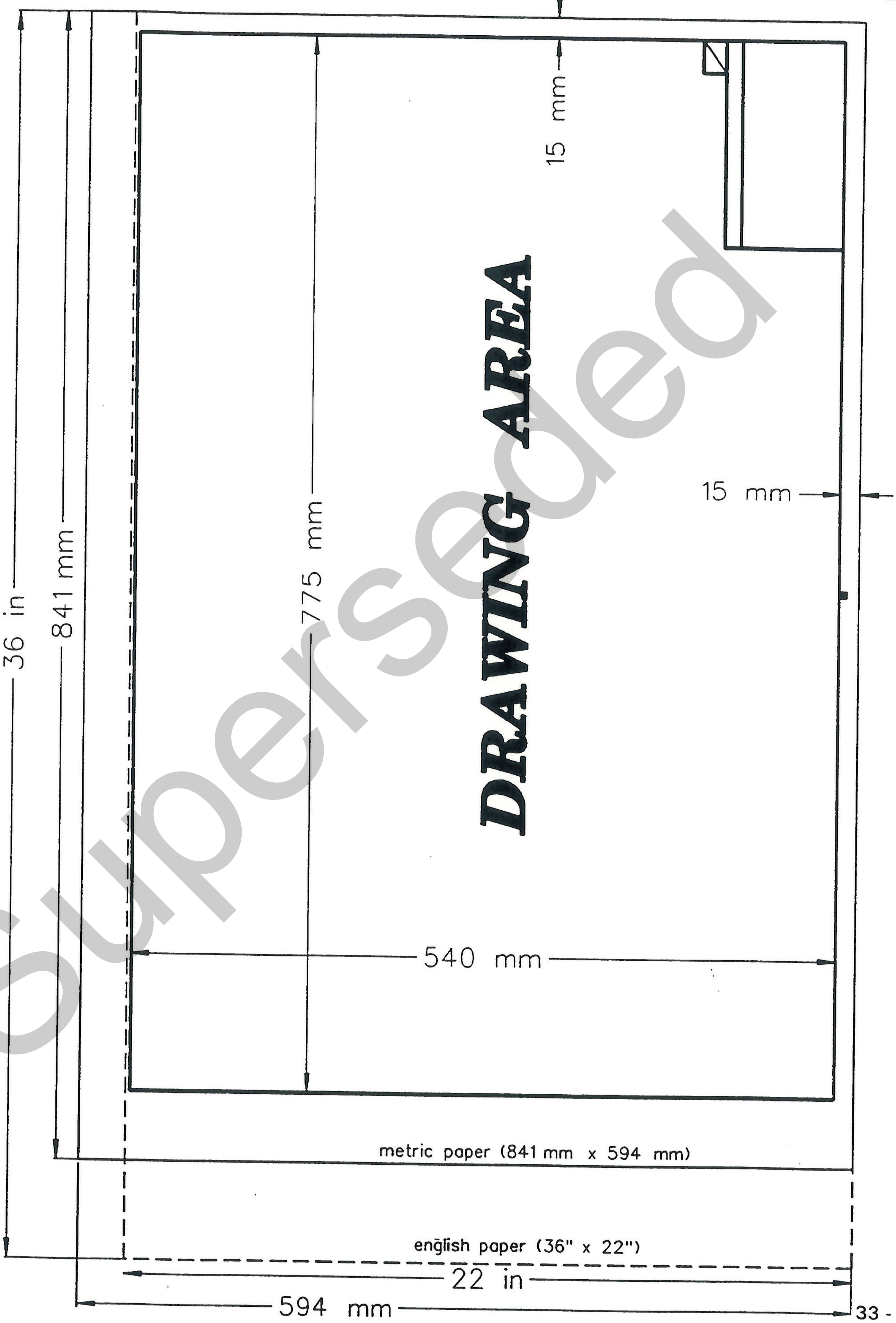
This bimonthly newsletter, ***Metric in Construction***, is available from the Construction Metrication Council of the National Institute of Building Sciences at no charge. Fax (*do not call*) NIBS at 202-289-1092. Include only the words "Metric newsletter" and your ***most concise*** mailing address. Please, one subscription per office. Phone orders will not be accepted.

The Council also publishes the ***Metric Guide for Federal Construction*** ($15.00) and ***Seven Metric Construction Case Studies: Preliminary Assessment*** ($12.00). For more information, contact the Publications Department, National Institute of Building Sciences, 1201 L Street N.W., Suite 400, Washington, DC 20005; phone 202-289-7800. Major credit cards and phone orders are accepted. Prices include shipping and handling.

English is the international language of business.
Metric is the international language of measurement.

National Institute of
BUILDING SCIENCES
1201 L Street, N.W., Suite 400
Washington, D.C. 20005

NONPROFIT
ORGANIZATON
U.S. POSTAGE
PAID
PERMIT NO. 3392
WASHINGTON, DC


DRAWING AREA
15 mm
15 mm
36 in
841 mm
775 mm
540 mm
metric paper (841 mm x 594 mm)
english paper (36" x 22")
22 in
594 mm

SUMMARY OF AASHTO GEOMETRIC GUIDELINES

I. CURBS

100 mm (3.94")
150 mm (5.91")

II. SIGHT DISTANCE

Stopping Sight Distance	Eye Height Object Height Headlight Height	1 070 mm (3.51 ft) 150 mm (5.91 in) 610 mm (2 ft)
Passing Sight Distance	Eye Height Object Height	1 070 mm (3.51 ft) 1 300 mm (4.27 ft)

III. HORIZONTAL CURVATURE

Radius definition should be used in lieu of degree of curve. Radius should be expressed in multiples of 5 m increments, where feasible.

IV. STRUCTURES

Long bridges will be those over 60 m in length.

V. STOPPING SIGHT DISTANCE (meters)

Design Speed (km/h)	Minimum	Desirable
30	30	30
40	50	50
50	60	70
60	80	90
70	100	120
80	120	140
90	140	170
100	160	210
110	180	250
120	210	290

VI. MINIMUM RADIUS DETERMINED FOR LIMITING VALUES OF e

Design Speed (km/h)	Maximum e	Rounded Radius (meters)
30	0.04	35
40	0.04	60
50	0.04	100
60	0.04	150
70	0.04	215
80	0.04	280
90	0.04	375
100	0.04	490
110	0.04	635
120	0.04	870
30	0.06	30
40	0.06	55
50	0.06	90
60	0.06	135
70	0.06	195
80	0.06	250
90	0.06	335
100	0.06	435
110	0.06	560
120	0.06	755

VII. DESIGN CONTROLS FOR CREST VERTICAL CURVES BASED ON STOPPING SIGHT DISTANCE (meters)

Design Speed (km/h)	Minimum	Desirable
30	3	3
40	5	5
50	9	10
60	14	18
70	22	31
80	32	49
90	43	71
100	62	105
110	80	151
120	102	202

VIII. DESIGN CONTROLS FOR SAG VERTICAL CURVES BASED ON STOPPING SIGHT DISTANCE (meters)

Design Speed (km/h)	Minimum	Desirable
30	4	4
40	8	8
50	11	12
60	15	18
70	20	25
80	25	32
90	30	40
100	37	51
110	43	62
120	50	73

D.1 STRUCTURAL STEEL

(Rolled Shapes, Channels, Angles and HP Shapes)

A draft version of "Metric Properties of Structural Shapes" is available from AISC. The metric dimensions are in accordance with the metric ASTM A 6M Specification. The new designation of a W 36 x 150 beam, for example, is W 920 x 223. The nominal depth is expressed in mm and the weight (mass) in kg/m.

D.1.1 Steel Plates

The steel industry has established standard metric plate thicknesses which will undoubtedly become the industry standard. These plate thicknesses are shown in the following table. To ensure availability it is recommended that thicknesses roughly equivalent to widely available current thicknesses be specified when possible. Millimeters will be used for all dimensions of steel plates, including width and length which must be specified to the full millimeter.

METRIC PLATE THICKNESSES			
Metric (mm)	English (in)	Metric (mm)	English (in)
5	0.1969	35	1.3780
5.5	0.2165	38	1.4961
6	0.2362	40	1.5748
7	0.2756	45	1.7717
8	0.3150	50	1.9685
9	0.3543	55	2.1654
10	0.3937	60	2.3622
11	0.4331	70	2.7559
12	0.4724	80	3.1496
14	0.5512	90	3.5433
16	0.6299	100	3.9370
18	0.7087	110	4.3307
20	0.7874	120	4.7244
22	0.8661	130	5.1181
25	0.9843	140	5.5118
28	1.1024	150	5.9055
30	1.1811	160	6.2992
32	1.2598		

D.1.2 High Strength Bolts

Bolt diameters shall be taken from ASTM Specification A 325M and A 490M as shown in the following table. Standard hole diameters are 2 mm larger than the diameters of M16 to M24 bolts, and 3 mm larger for M27 and larger bolts. The usual 7/8" diameter bolt in a 15/16" hole shall be noted as M22 A 325M, open holes 24 mm. The usual 1-1/4" diameter bolt in a 1-5/16" hole shall be noted as M30 A 325M, open holes 33 mm.

METRIC HIGH STRENGTH BOLT DIAMETERS	
Metric Size - Diameter mm (inches)	**Approximate Size Replaced (inches)**
M 16 (0.64)	5/8 (0.625)
M 20 (0.80)	3/4 (0.750)
M 22 (0.88)	7/8 (0.875)
M 24 (0.96)	1 (1.000)
M 27 (1.08)	1-1/8 (1.125)
M 30 (1.20)	1-1/4 (1.250)
M 36 (1.44)	1-1/2 (1.500)

There may be some instances where metric bolts have not been crash tested in safety related features (breakaway sign mounts, guide rail connections, etc.). In these cases, English size bolts shall be specified on the plans.

D.2 REINFORCING STEEL

A new series of reinforcing steel sizes will be used. The metric dimensions shall be in accordance with ASTM A 615M, as shown in the following table:

ASTM A 615M CHART FOR REINFORCING STEEL BARS				
Metric Bar Size Designation	**Nominal Mass (kg/m)**	**Nominal Dimensions**		**Comparison to A 615 Based on Bar Area**
		Diameter (mm)	**Cross Sectional Area (mm^2)**	
10M	0.785	11.3	100	22% < #4
15M	1.570	16.0	200	SAME AS #5
20M	2.355	19.5	300	6% > #6
25M	3.925	25.2	500	2% < #8
30M	5.495	29.9	700	9% > #9
35M	7.850	35.7	1 000	1% < #11
45M	11.775	43.7	1 500	3% > #14
55M	19.625	56.4	2 500	3% < #18

Note that the metric bar size designations are roughly equivalent to the bar diameter in millimeters.

For comparison purposes, the following table is also presented:

ASTM A 615 CHART FOR REINFORCING STEEL BARS						
Inch-Pound Bar Size Designation	Nominal Weight		Nominal Dimensions			
			Diameter (mm)		Cross Sectional Area	
	lb/ft	(kg/m)	in	(mm)	in^2	(mm^2)
#3	0.376	(.560)	0.375	(9.5)	0.11	(71)
#4	0.668	(.994)	0.500	(12.7)	0.20	(129)
#5	1.043	(1.552)	0.625	(15.9)	0.31	(200)
#6	1.502	(2.235)	0.750	(19.1)	0.44	(284)
#7	2.044	(3.042)	0.875	(22.2)	0.60	(387)
#8	2.670	(3.974)	1.000	(25.4)	0.79	(510)
#9	3.400	(5.060)	1.128	(28.7)	1.00	(645)
#10	4.303	(6.404)	1.270	(32.3)	1.27	(819)
#11	5.313	(7.907)	1.410	(35.8)	1.56	(1 006)
#14	7.65	(11.39)	1.693	(43.0)	2.25	(1 452)
#18	13.60	(20.24)	2.257	(57.3)	4.00	(2 581)

Metric reinforcing bars shall be detailed using the "M" suffix to emphasize that metric bars are being designated. Bars should be detailed to the nearest 25 mm total length.

The following grades of metric rebars are currently available, based on their minimum yield strength. Grade 400 replaces the commonly used Grade 60 English rebars, and are available in all sizes.

GRADES OF METRIC REBARS			
	Grade 300	Grade 400	Grade 500
Tensile Strength, minimum (MPa)	500 (72.6 ksi)	600 (87.1 ksi)	700 (101.6 ksi)
Yield Strength, minimum (MPa)	300 (43.5 ksi)	400 (58.0 ksi)	500 (72.6 ksi)

Grade 300 bars are available only in sizes 10M thru 20M.
Grade 500 bars are available only in sizes 35M, 45M, and 55M.

If the reinforcing steel area "A_s" in in^2/ft is known, the equivalent millimeter spacing for a given size of metric bar is closely approximated by:

Spacing (mm) = (12/25.4) · (58/60) · A_m/A_s for Grade 400 reinforcing steel
Spacing (mm) = (.457) · A_m / A_s

A_m = Area of one metric bar in mm^2
A_s = Required reinforcing steel area in in^2/ft

Equivalent metric bar spacing for temperature steel is:

#4 @ 1'-0" using 10M bars = (.457)(100)/.20 = 229 mm: Use 10M @ 225 mm
#4 @ 1'-6" using 10M bars = (.457)(100)/.133 = 344 mm: Use 10M @ 340 mm
#5 @ 2'-0" using 15M bars = (.457)(200)/.155 = 590 mm: Use 15M @ 590 mm

D.3 PRESTRESSED CONCRETE BEAMS

Until new standards are developed by the prestressed concrete industry, all beam dimensions, strand diameters, and strand spacing will be soft converted into metric units and shown to the closest millimeter.

D.4 INTERIM METRIC CONVERSION PRACTICES

Since AASHTO has not yet established official metric conversions for most structural units, the following interim conversions shall be used. The list is not complete and is intended only to provide converted values for the most commonly used units. The 15th AASHTO Standard Specifications for Highway Bridges - 1992 has many converted formulas in Appendix E. Typographical and conversion errors have been noted. The designer must review the accuracy of the formulas until an errata sheet is published.

LIVE LOADS:

Moments, shears, and reactions resulting from standard AASHTO truck and lane loadings must be converted to metric equivalents.

Truck Loadings:						
	English	H 15	HS 15	H 20	HS 20	HS 25
	Metric	M 13.5	MS 13.5	M 18	MS 18	MS 22.5

MINIMUM VERTICAL CLEARANCES:

Feature Below	Metric	English
Interstate freeways, expressways, turnpikes	5.1 m (16.73 ft)	16'-6"
State routes, county routes, local roads, parkways	4.8 m (15.75 ft)	15'-6"
Railroads (non-electrified)	7.0 m (22.97 ft)	23'-0"
Railroads (electrified)	7.5 m (24.61 ft)	24'-6"

DEAD LOADS:

Item	Metric	English
Future wearing surface	1.2 kN/m^2	25 psf
SIP forms with additional concrete	0.6 kN/m^2	13 psf
Reinforced concrete	23.6 kN/m^3	150 pcf
Earth	18.9 kN/m^3	120 pcf
Water	9.8 kN/m^3	62.4 pcf
Lateral soil pressure (equiv. fluid pressure)	5.5 kN/m^3	35 pcf
Structural steel	77.0 kN/m^3	490 pcf

MATERIAL STRENGTHS:

Item	Metric	English
Structural steel	Grade 250 (F_y = 250 MPa)	Grade 36 (F_y = 36 ksi)
Structural steel	Grade 345(F_y = 345 MPa)	Grade 50 (F_y = 50 ksi)
Reinforcing steel	Grade 400 (F_y = 400 MPa)	Grade 60 (F_y = 60 ksi)
Prestressing strands	1 860 MPa	270 000 psi
Concrete (f'c)	21 MPa	3 000 psi
	28 MPa	4 000 psi
	34 MPa	5 000 psi
	41 MPa	6 000 psi

PILES:

Item	Metric	English
Length (to nearest)	250 mm	12 in
Spacing (preferred)	1 000 mm	36 in
Embedment in concrete	300 mm	1 ft
Spacing (minimum)	1 000 mm	3 ft

REINFORCING STEEL CLEARANCE (Cover or C/C spacing dimensions):

Metric	English
25 mm	1"
40 mm	1-1/2"
50 mm	2"
65 mm	2-1/2"
75 mm	3"
100 mm	4"