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Standard Practice for Use of Metric (SI) Units in Building Design and Construction[1] (Committee E-6 Supplement to E380)

This standard is issued under the fixed designation E 621; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ϵ^1 NOTE—Section 11 was added editorially in April 1999.

INTRODUCTION

The International System of Units (SI) was developed by the General Conference on Weights and Measures (CGPM), which is an international treaty organization. The abbreviation SI, derived from the French "Système International d'Unités," is used in all languages.

SI is a rational, coherent, international, and preferred measurement system which is derived from earlier decimal metric systems but supersedes all of them.

The use of the metric system in the United States was legalized by an Act of Congress in 1866, but was not made obligatory.

The *Meric Conversion Act of 1975*, as amended by the *Omnibus Trade and Competitiveness Act of 1988*, established the modernized metric system (SI) as the preferred system of measurement in the United States and required that, to the extent feasible, it be used in all federal procurement, grants, and business-related activities. Executive Order 12770 of July 25, 1991, *Metric Usage in Federal Government Programs*, mandated that federal agencies prepare metric transition plans, add metric units to their publications, and work with other governmental, trade, professional, and private sector metric organizations on metric implementation.

In the building design and construction community the application of SI units, together with preferred numerical values, will simplify and speed up calculations and facilitate all measurement intensive activity.

This document has been prepared to provide a single, comprehensive, and authoritative standard for SI units to be used in building design, product manufacture, and construction applications.

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[1] This practice is under the jurisdiction of ASTM Committee E-6 on Performance of Buildings and is the direct responsibility of Subcommittee E06.62 on Coordination of Dimensions for Building Materials and Systems.

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1. Scope

1.1 This standard outlines a selection of SI units, with multiples and submultiples, for general use in building design and construction.

1.2 In addition, rules and recommendations are given for the presentation of SI units and symbols, and for numerical values shown in conjunction with SI.

1.3 A selection of conversion factors appropriate for use within the construction community is given in Appendix X1.

1.4 The SI units included in this document comply with and augment the ASTM Standard for Metric Practice E 380– 82 and are generally consistent with International Standards Organization (ISO) 1000 – 1981 SI Units and Recommendations for the Use of Their Multiples and Certain Other Units, and the ISO/31 Series of Standards, Quantities, and Units of SI.

2. Terminology

2.1 *Definitions:*

2.1.1 *SI*—The International System of Units (abbreviation for "le Système International d'Unités) as defined by the General Conference on Weights and Measures (CGPM)—based upon seven base units, two supplementary units, and derived units, which together form a coherent system.

2.1.2 *quantity*—measurable attribute of a physical phenomenon. There are base units for seven quantities and supplementary units for two quantities upon which units for *all* other quantities are founded.

2.1.3 *unit*—reference value of a given quantity as defined by CGPM Resolution or ISO Standards. There is *only one* unit for each quantity in SI.

2.1.4 *coherent unit system*—system in which relations between units contain as numerical factor only the number "one" or "unity," because all derived units have a unity relationship to the constituent base and supplementary units.

2.1.5 *numerical value of a quantity*—magnitude of a quantity expressed by the product of a number and the unit in which the quantity is measured.

3. The Concept of SI

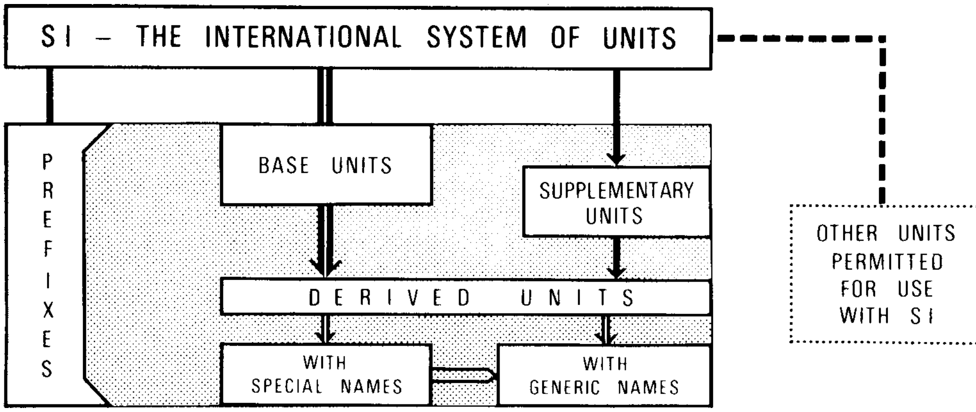
3.1 The International System of Units (SI) was developed to provide a universal, coherent, and preferred system of measurement for world-wide use and appropriate to the needs of modern science and technology.

3.2 The principal features of SI are:

3.2.1 There is only one recognized unit for each physical quantity.

3.2.2 The system is fully coherent; this means that all units in the system relate to each other on a unity (one-to-one) basis.

3.2.3 A set of internationally agreed prefixes can be attached to units to form preferred multiples and submultiples of 10



raised to a power that is a multiple of 3. This provides for convenient numerical values when the magnitude of a quantity is stated.

3.2.4 Units and their prefixes are represented by a set of standardized and internationally recognized symbols.

3.3 Because of their practical significance, the use of additional non-SI units in conjunction with SI is permitted for some quantities.

3.4 SI units, permissible non-SI units, and prefixes are discussed in Sections 4, 5, and 6.

3.5 The diagram below shows graphically the types of units within SI or associated with SI:

4. SI Units

4.1 The International System of Units (SI) has three classes of units:

4.1.1 Base units for independent quantities,

4.1.2 Supplementary units for plane angle and solid angle, and

4.1.3 Derived units.

4.2 The seven base units and two supplementary units are unique units which, except for the kilogram (Note 1), are defined in terms of reproducible phenomena.

NOTE 1—The primary standard for mass is the international prototype kilogram maintained under specified conditions at the International Bureau of Weights and Measures (BIPM) near Paris in France.

4.3 Derived units can all be defined in terms of their derivation from base and supplementary units. They are listed in two categories:

4.3.1 Derived units with *special* names and symbols, and

4.3.2 Derived units with *generic* or complex names.

4.4 A chart, indicating diagrammatically the relationship between the base units, supplementary units, and derived units that have been given special names, is shown in Appendix X2.

4.5 Table 1 contains base, supplementary, and derived units of significance in design and construction, listing:

4.5.1 Quantity,

4.5.2 Unit name,

4.5.3 Unit symbol,

4.5.4 Unit formula,

4.5.5 Unit derivation (in terms of base and supplementary units), and

4.5.6 Remarks.

5. Non-SI Units for Use with SI

5.1 There is an additional group of acceptable, but non-coherent traditional units retained in association with SI, because of their practical significance in general applications.

5.2 Non-SI units of significance to design and construction are shown in Table 2, under two categories:

5.2.1 Units for general use, and

5.2.2 Units for limited application only.

5.3 Appendix X3 shows a group of superseded metric units not recommended for use with SI in design and construction applications.

6. SI Unit Prefixes

6.1 SI is based on the decimal system of multiples and submultiples, and therefore the use of common fractions is minimized. Multiples are formed by attaching standard prefixes to SI units.

6.2 Preferred multiples range in geometric steps of 1000 (10^3) up to 10^{18}; submultiples range in geometric steps of 1/1000 (10^{-3}) down to 10^{-18}.

6.3 *Preferred Multiples and Submultiples*—The preferred prefixes shown in Table 3 are relevant in design and construction. Prefixes outside the range 10^{-6} (micro) to 10^6 (mega) will occur only in rare instances.

6.4 *Other Multiples for Limited Application*—SI includes a number of additional historically used multiples and submultiples, shown in Table 4, but these should be avoided as far as possible.

7. Rules and Recommendations for the Use of SI

7.1 Two tables of rules and recommendations have been prepared to facilitate the correct application of SI units and symbols and the correct presentation of units, symbols, and numerical values shown in conjunction with units and symbols.

7.2 Table 5 gives "Rules and Recommendations for the Presentation of SI Units and Symbols."

7.3 Table 6 gives guidance on "Presentation of Numerical Values with SI."

7.4 The tables provide a convenient reference guide for the editorial checking of metric documents to ensure that the presentation of data is in line with accepted practice.

8. SI Units for Use in Design and Construction

8.1 Correct selection of units for use in building design calculations and in documentation is essential to minimize errors and to optimize the coordination between the various sectors and groups within the construction community.

8.2 Tables 7-13 list SI units, and other units acceptable with SI as recommended, for use in building design and construction related activities. Where appropriate, working ranges are indicated for selected units, and typical examples of their field(s) of application provided. In addition, explanatory remarks are provided to briefly deal with special considerations.

8.3 The following subdivision has been adopted:

Table 7	Space and Time: Geometry, Kinematics, and Periodic Phenomena
Table 8	Mechanics: Statics and Dynamics
Table 9	Heat, Thermal Effects, Heat Transfer
Table 10	Moisture Movement
Table 11	Electricity and Magnetism
Table 12	Lighting
Table 13	Acoustics

8.4 *Preferred Range of Values*—The use of an appropriate unit or multiple of a unit depends upon the context in which it is used.

8.4.1 In printed or typed material it is preferable to use numbers between 1 and 1000, wherever possible, by selecting an appropriate prefix. For example: 725 m is preferred to 0.725 km or 725 000 mm.

TABLE 1 Units in the International System—SI

Unit Group	Quantity	Unit Name	Symbol	Formula	Unit Derivation	Remarks
Base Units:						
	Length	metre	m			
	Mass	kilogram	kg			
	Time	second	s			Already in common use
	Electric current	ampere	A			Already in common use
	Thermodynamic temperature	kelvin	K			The customary unit for temperature is the degree Celsius (°C).
	Amount of substance	mole	mol			The "mol" has no application in construction.
	Luminous intensity	candela	cd			Already in common use
Supplementary Units:						
	Plane angle	radian	rad			Already in common use
	Solid angle	steradian	sr			Already in common use
Derived Units with Special Names:						
	Frequency (of a periodic phenomenon)	hertz	Hz	l/s	s^{-1}	The hertz replaces "cycle per second."
	Force	newton	N	$kg·m/s^2$	$m·kg·s^{-2}$	
	Pressure, stress, elastic modulus	pascal	Pa	N/m^2	$m^{-1}·kg·s^{-2}$	
	Energy, work, quantity of heat	joule	J	N·m	$m^2·kg·s^{-2}$	
	Power, radiant flux	watt	W	J/s	$m^2·kg·s^{-3}$	Already in common use
	Quantity of electricity, electric charge	coulomb	C	A·s	s·A	Already in common use
	Electric potential, potential difference, electromotive force	volt	V	J/C or W/A	$m^2·kg·s^{-3}·A^{-1}$	Already in common use
	Electric capacitance	farad	F	C/V	$m^{-2}·kg^{-1}·s^4·A^2$	Already in common use
	Electric resistance	ohm	Ω	V/A	$m^2·kg·s^{-3}·A^{-2}$	Already in common use
	Electric conductance	siemens	S	A/V or l/Ω	$m^{-2}·kg^{-1}·s^3·A^2$	The 'siemens' was formerly referred to as "mho."
	Magnetic flux	weber	Wb	V·s	$m^2·kg·s^{-2}·A^{-1}$	Already in common use
	Magnetic flux density	tesla	T	Wb/m^2	$kg·s^{-2}·A^{-1}$	Already in common use
	Electric inductance	henry	H	Wb/A	$m^2·kg·s^{-2}·A^{-2}$	Already in common use
	Celsius temperature	degree Celsius	°C	K		See 9.7
	Luminous flux	lumen	lm	cd·sr	cd·sr	Already in common use
	Illuminance	lux	lx	lm/m^2	$m^{-2}·cd·sr$	
	Activity (of a radionuclide)	becquerel	Bq	l/s	s^{-1}	No application in construction.
	Absorbed dose	gray	Gy	J/kg	$m^2·s^{-2}$(*)	(*) kg is canceled out. No application in construction.
Derived Units with Generic Names:						
a. *Units Expressed in Terms of One Base Unit:*						
	Area	square metre	m^2		m^2	
	Volume, capacity	cubic metre	m^3		m^3	(1 m^3 = 1000 L)
	Section modulus	metre to third power		m^3	m^3	
	Second moment of area	metre to fourth power		m^4	m^4	
	Curvature	reciprocal (of) metre		l/m	m^{-1}	Revolution per second (r/s) is used in specifications for rotating machinery.
	Rotational frequency	reciprocal (of) second	l/s	s^{-1}		
	Coefficient of linear thermal expansion	reciprocal (of) kelvin		l/K	K^{-1}	

TABLE 1 *Continued*

Unit Group	Quantity	Unit Name	Symbol	Formula	Unit Derivation	Remarks
b. *Units Expressed in Terms of Two or More Base Units:*						
	Linear velocity	metre per second	m/s	$m\cdot s^{-1}$		
	Linear acceleration	metre per second squared	m/s^2	$m\cdot s^{-2}$		
	Kinematic viscosity	square metre per second	m^2/s	$m^2\cdot s^{-1}$		
	Volume rate of flow	cubic metre per second	m^3/s	$m^3\cdot s^{-1}$		
	Specific volume	cubic metre per kilogram	m^3/kg	$m^3\cdot kg^{-1}$		
	Mass per unit length	kilogram per metre	kg/m	$m^{-1}\cdot kg$		
	Mass per unit area	kilogram per square metre	kg/m^2	$m^{-2}\cdot kg$		
	Density (mass per unit volume)	kilogram per cubic metre	kg/m^3	$m^{-3}\cdot kg$		In this SI form, mass density is conveniently 1000 times specific gravity.
	Moment of inertia	kilogram metre squared	$kg\cdot m^2$	$m^2\cdot kg$		
	Mass flow rate	kilogram per second	kg/s	$kg\cdot s^{-1}$		
	Momentum	kilogram metre per second	kg·m/s	$m\cdot kg\cdot s^{-1}$		
	Angular momentum	kilogram metre squared per second	$kg\cdot m^2/s$	$m^2\cdot kg\cdot s^{-1}$		
	Magnetic field strength	ampere per metre	A/m	$m^{-1}\cdot A$		
	Current density	ampere per square metre	A/m^2	$m^{-2}\cdot A$		
	Luminance	candela per square metre	cd/m^2	$m^{-2}\cdot cd$		
c. *Units Expressed in Terms of Base Units and/or Derived Units with Special Names:*						
	Moment of force, torque	newton metre	N·m	$^2\cdot kg\cdot s^{-2}$		
	Flexural rigidity	newton square metre	$N\cdot m^2$	$m^3\cdot kg\cdot s^{-2}$		
	Force per unit length, surface tension	newton per metre	N/m	$kg\cdot s^{-2}$(1)		(1) m is canceled out
	Dynamic viscosity	pascal second	Pa·s	$m^{-1}\cdot kg\cdot s^{-1}$		
	Impact ductility	joule per square metre	J/m^2	$kg\cdot s^{-2}$(2)		(2) m^2 is canceled out
	Combustion heat (per unit volume)	joule per cubic metre	J/m^3	$m^{-1}\cdot kg\cdot s^{-2}$		
	Combustion heat (per unit mass), specific energy, specific latent heat	joule per kilogram	J/kg	$m^2\cdot s^{-2}$(3)		(3) kg is canceled out
	Heat capacity, entropy	joule per kelvin	J/K	$m^2\cdot kg\cdot s^{-2}\cdot K^{-1}$		
	Specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg·K)	$m^2\cdot s^{-2}\cdot K^{-1}$ (4)		(4) kg is canceled out
	Heat flux density, irradiance, sound intensity	watt per square metre	W/m^2	$kg\cdot s^{-3}$(5)		(5) m^2 is canceled out
	Thermal conductivity	watt per metre kelvin	W/(m·K)	$m\cdot kg\cdot s^{-3}\cdot K^{-1}$		(6) m^2 is canceled out
	Thermal conductance	watt per square metre kelvin	$W/(m^2\cdot K)$	$kg\cdot s^{-3}\cdot K^{-1}$(6)		
	Thermal resistance	square metre kelvin per watt	$K\cdot m^2/W$	$kg^{-1}\cdot s^3\cdot K$ (7)		(7) m^2 is canceled out
	Electric field strength	volt per metre	V/m	$m\cdot kg\cdot s^{-3}\cdot A^{-1}$		
	Electric flux density	coulomb per square metre	C/m^2	$m^{-2}\cdot s\cdot A$		
	Electric charge density	coulomb per cubic metre	C/m^3	$m^{-3}\cdot s\cdot A$		
	Electric permittivity	farad per metre	F/m	$m^{-3}\cdot kg^{-1}\cdot s^4\cdot A^2$		
	Electric permeability	henry per metre	H/m	$m\cdot kg\cdot s^{-2}\cdot A^{-2}$		
	Electric resistivity	ohm metre	Ω·m	$m^3\cdot kg\cdot s^{-3};\cdot A^{-2}$		
	Electric conductivity	siemens per metre	S/m	$m^{-3}\cdot kg^{-1}\cdot s^3\cdot A^2$		
	Light exposure	lux second	lx·s	$m^{-2}\cdot s\cdot cd\cdot sr$		
	Luminous efficacy	lumen per watt	lm/W	$m^{-2}\cdot kg^{-1}\cdot s^3\cdot cd\cdot sr$		
d. *Units Expressed in Terms of Supplementary Units and Base and/or Derived Units:*						
	Angular velocity	radian per second	rad/s	$s^{-1}\cdot rad$		
	Angular acceleration	radian per second squared	rad/s^2	$m^{-2}\cdot rad$		
	Radiant intensity	watt per steradian	W/sr	$m^2\cdot kg\cdot s^{-3}\cdot sr^{-1}$		
	Radiance	watt per square metre steradian	$W/(m^2\cdot sr)$	$kg\cdot s^{-3}\cdot sr^{-1}$(8)		(8) m^2 is canceled out

8.4.2 If the numerical quantity is part of a group of numbers in a different range, select the prefix that most adequately covers the range, without unduly large or small numbers. For example: If 725 m is part of a group of numbers shown in kilometres, show it as 0.725 km.

8.4.3 Although physical data generally should be presented in the most condensed form possible, by using appropriate prefixes, it will be advantageous in calculations to use exponential notation, instead of prefixes, for example: 900 mm^2= 0.9×10^{-3} m^2; 36 MPa = 36 $\times$ 10^6 Pa = 36 $\times$ 10^6 N/m^2.

8.4.4 In drawings it will be of advantage to show one measurement unit throughout, so that numerical values can be represented by numbers only, and the unit symbol can be deleted. For example, in a drawing on which all dimensions are shown in millimetres, 5-digit numbers (indicating millimetres) are quite acceptable.

9. Special Considerations in the Use of SI Units in Building Design and Construction

9.1 *Linear Measurement (Length)*:

9.1.1 The preferred units for measurement of length in building design, construction, and production are the millimetre (mm) and the metre (m).

9.1.2 In special applications, the kilometre (km) is used for the measurement of long distances, and the micrometre (µm) is used for precision measurements.

9.1.3 The centimetre (cm) is to be avoided in all building design and construction applications.

9.1.4 The reasons for the deletion of the centimetre are:

9.1.4.1 The centimetre is not consistent with the preferred use of multiples that represent ternary powers of 10.

9.1.4.2 The order of magnitude between millimetre and centimetre is only 10, and the use of both units would lead to confusion.

TABLE 2 Other Units Whose Use Is Permitted with SI

Quantity	Unit Name	Symbol	Relationship to SI Unit	Remarks
Units for General Use:				
Volume	litre[A]	L	1 L = 0.001 m^3 = 10^6 mm^3	The litre may only be used with the SI prefix "milli."
Mass	metric ton[B]	t	1 t = 1000 kg = (1 Mg)	
Time	minute	min	1 min = 60 s	See also Section 9.6.
	hour	h	1 h = 3600 s = (60 min)	
	day (mean solar)	d	1 d = 86 400 s = (24 h)	
	year (calendar)	a	1 a = 31 536 000 s = (365 d)	
Plane angle	degree (of arc)	°	1° = 0.017 453 rad = 17.453 mrad	1° = (π/180) rad
Velocity	kilometre per hour	km/h	1 km/h = 0.278 m/s	1 m/s = 3.6 km/h
Units Accepted for Limited Application Only:				
Area	hectare	ha	1 ha = 10 000 m^2	For use in land measurement.
Energy	kilowatthour	kWh	1 kWh = 3.6 MJ	For measurement of electrical energy consumption only.
Speed of rotation	revolution per minute	r/min	1 r/min =	To measure rotational speed in slow-moving equipment only.

[A]The international symbol for "litre" is the lowercase "l", which can be easily confused with the numeral "1." Several English-speaking countries have adopted the script "ℓ" as symbol for "litre" in order to avoid any misinterpretation. The symbol "L" (capital ell) has been adopted for United States use to prevent confusion.

[B]The international name for "metric ton" is "tonne." The metric ton is equal to the "megagram" (Mg).

TABLE 3 Preferred Multiples and Submultiples

Multiplication Factor			Prefix		Pronunciation
			Name	Symbol	
10^{12}	or	1 000 000 000 000	tera	T	as in *terra*ce
10^{9}	or	1 000 000 000	giga	G	jig'a
10^{6}	or	1 000 000	mega	M	as in *mega*phone
10^{3}	or	1 000	kilo	k	kill'oh
10^{-3}	or	0.001	milli	m	as in *mili*tary
10^{-6}	or	0.000 001	micro	µ	as in *micro*phone
10^{-9}	or	0.000 000 001	nano	n	nan'oh
10^{-12}	or	0.000 000 000 001	pico	p	peek'oh

9.1.4.3 The millimetre (mm) provides integers withinappropriate tolerances for all building dimensions and nearly all building product dimensions, so that decimal fractions are almost entirely eliminated from documents. In contrast, acceptance of the centimetre would inevitably lead to extensive use of decimal fractions, which is undesirable.

9.1.5 On drawings, unit symbols may be deleted if the following rules are applied:

9.1.5.1 The drawing is designated "all dimensions shown in millimetres unless otherwise noted" or "all dimensions shown in metres unless otherwise noted."

9.1.5.2 Whole numbers always indicate millimetres, for example, 3600; 300; 25.

(1) Any length up to 328 ft can be shown by a simple 5-digit number, for example, 327 ft 10¹¹⁄₁₆ in. = 99 941 mm.

(2) Similarly, any length up to 32 ft 9 in. can be shown by a 4-digit number; any length up to 3 ft 3⁵⁄₁₆ in. can be shown by a 3-digit number.

TABLE 4 Other Multiples for Limited Application

Multiplication Factor	Prefix Name	Prefix Symbol	Pronunciation
10^2 or 100	hecto	h	heck'toe
10^1 or 10	deka	da	deck'a
10^{-1} or 0.1	deci	d	as in *deci*mal
10^{-2} or 0.01	centi	c	as in *senti*ment

(3) Decimalized expressions taken to three places always indicate metres, for example, 3.600; 0.300; 0.025.

9.1.6 The use of millimetres and metres, as recommended, saves both space and time in drawing, typing, and computer applications, and it also improves clarity in drawings with a lot of dimensions.

9.1.7 *Survey Measurement*—The change to SI units will also eliminate the discrepancies between "international" foot and "U.S. survey" foot, "international" mile and "U.S. survey" mile (the survey mile is approximately 3 mm longer), and corresponding derived units for area measurement.

NOTE 2—Since 1893, the U. S. basis of length measurement has been derived from metric standards. In 1959, the definition of the length of the "foot" was changed from 1200/3937 m to 0.3048 m exactly, which resulted in the new value being shorter by two parts in a million.

At the same time it was decided that any data derived from and published as a result of geodetic surveys within the United States would remain with the old standard.

Thus all land measurements in U. S. customary units are based upon the" U. S. survey foot" which relates to the metre by the old standard (1200/3937 = 0.304 800 6 m).

9.2 *Area*:

9.2.1 The preferred unit for area measurement is the square metre (m^2). Very large areas can be expressed in square kilometres km^2), and small areas will be expressed in square millimetres (mm^2), or in square metres using exponential notation (for example, 10^{-6} m^2).

9.2.2 The hectare (ha) is used for land and water measurement *only*. (1 ha = $(100\ m)^2$= 10 000 m^2= 10^4 m^2= 10^{-2} km^2).

9.2.3 The square centimetre (cm^2) is to be avoided to minimize confusion. Any measurement given in square centimetres should be converted to square millimetres or square metres. (1 cm^2= 100 mm^2= 10^{-4} m^2).

9.2.4 At times, it will be more appropriate to indicate the surface or cross-sectional area of building products by linear dimensions, for example, 40 by 90 mm; 300 by 600. It is preferred practice to indicate the width dimension first and height second.

TABLE 5 Rules and Recommendations for the Presentation of SI Units and Symbols

	Typical Examples	Remarks
A. *Generak*		
1. All unit names should be denoted by correct symbols or be written in full. In the interest of simplification and to reduce the amount of writing, use unit symbols rather than fully written forms.	USE: J/kg or joule per kilogram	NOT: joule per kg NOT: J/kilogram
2. DO NOT USE mixtures of names and symbols.		
B. *Symbols for Unit Quantities and Prefixes*		
1. SI symbolsmare internationally agreed and there is only *one* symbol for each unit. Multiples and submultiples are formed by using the unit symbol and attaching a prefix symbol in front of it.	m, kg, s, A, cd, K, L	See also B.5-B.7
2. All unit symbols are shown in upright letters, and cn be produced by a normal typewritter keyboard with the exceptions of the symbols for the SI unit ″ohm″ and the prefix ″micro″ which are represented by Greek letters ″Ω″ and ″μ″ respectively.		EXCEPTIONS: Ω,
3. Unit symbols are NEVER followed by a period (full stop) except at the end of a sentence.	60 kg/m	NOT: 60 kg./m.
4. Unit symbols are normally written in lowercase, except for unit names derived from a proper name, in which case the initial is capitalized. Some units have symbols consisting of two letters from a proper name, of which *only* the first letter is capitalized. (The symbol for the unit name ″ohm″ is the capital Greek letter Ω.)	m, kg, s, mol, cd, etc. A, K, N, J, W, V, etc. Pa, Hz, Wb, etc.	EXCEPTION: L
5. Prefixes for magnitudes from 10^6 to 10^{18} have capital upright letter symbols.	M, G, T, etc.	See also C.1
6. Prefixes for magnitudes from 10^{-18} through to 10^3 have lowercase upright letter symbols. (The symbol for 10^{-6} or micro is the lowercase Greek letter μ.)	p, n, μ, m, k, etc.	See also C.1
7. Prefix symbols are directly attached to the unit symbol, *without a space* between them.	mm, kW, MN, etc.	NOT: m m, k W, M N
8. DO NOT USE compound prefixes to form a multiples of submultiple of a unit (for example, USE nanometre, DO NOT USE micromillimetre *or* millimicrometre).	nm	NOT: μmm or mμm
9. In the case of the base unit kilogram, prefixes are attached to the ″gram″ (for example, milligram, NOT microkilogram).	mg	NOT: μkg

TABLE 5 *Continued*

	Typical Examples	Remarks
10. USE ONLY ONE PREFIX when forming a multiple of a submultiple of a compound unit.	km/s; mV/m	NOT: mm/μs; μV/mm EXCEPTION: MJ/kg NOT kJ/g.
11. Any prefix should appear only in the numerator and never in the denominator with the exception of the base unit kg.	MN/m	NOT: kN/mm
C. *Areas of Possible Confusion Requiring Special Cre*		
1. The symbols for SI units and the conventions that govern their use shall be followed. Anumber of prefix and unit symbols use the same letter, but in different form. EXERCISE CARE to ppresent the correct symbol for each unit and ppprefix.	g (gram); G (giga) k (kilo); K (kelvin) m (milli); M (mega) m (metre) n (nano); N (newton)	*OTHERS:* c (cent); C (coulomb) °C (degree Celsius) s (second); S (siemens) t (metric ton); T (tera) T (tesla)
2. All prefix and unit symbols retain their prescribed form regardless of the surrounding typography. In printouts from limited character sets (telex, computer printers) special considerations apply to symbols for mega, micro, ohm, and siemens. Where confusion is likely to arise, WRITE UNITS IN FULL.		
D. *Unit Names Written Out in Full*		
1. Unit names, including prefixes, are treated as common names and are *not capitalized*, except at the beginning of sentences ot in titles. (The only exception is ″Celsius″ in ″ degree Celsius,″ where degree is considered as the unit name and is shown in lowercase, while Celsius represents an adjective and is capitalized.)	metre, newton, etc.	NOT: Metre, Newton EXCEPTION: degree Celsius
2. Where a prefix is attached to an SI unit to form a multiple or submultiple, the combination is written as one word. (There are three cases where the final vowel of the prefix is omitted in the combination: megohm, kilohm, and hectare,)	millimetre; kilowat	NOT: milli-metre NOT: kilo-watt
3. Where a compound unit is formed by multiplication of two units, the use of a space between units is preferred, but a hyphen is acceptable and in some situations more appropriate, to avoid any risk of misinterpretation.	newton-metre *or* newton-metre	NOT: newtonmetre
4. Where a compound unit is formed by division of two units, this is expressed by inserting ″per″ between the numerator and the denominator.	metre per second joule per kelvin	NOT: metre/second NOT: joule/kelvin
5. Where the numerical value of a unit is written in full, the unit should also be written in full.	seven metres	NOT: seven m
E. *Plurals*		
1. Units written in full are subject to the normal rules of grammer. For any unit with a numerical value greater than one (1), an ″S″ is added to the written unit to denote the plural.	1.2 Metres; 2.3 newtons; 33.2 kilograms	BUT: 0.8 metre
2. The following units have the same plural as singular when written out in full: hertz, lux, siemens.	350 kilohertz 12.5 lux	
3. Symbols NEVER change in the plural.	2.3 N; 33.2 kg	
F. *Compound Unit Symobols–Products and Quotients*		
1. The products of two units is indicated by a dot placed at min-height between the unit symbols.	kN · m; Pa · s	NOT: kNm; Pas NOT: kN m; Pa s
2. To express a derived unit formed by division, any one of the following methods my be used:		
a. a solidus (slash, /)	kg/m^3; W/(m · K)	See also F.3 and F.5
b. a horizontal line between numerator and denominator	$\frac{kg}{m^3}$; $\frac{W}{m \cdot K}$	
c. a negative index (or negative power)	kg ·$^{m-3}$; W ·$^{m-1}$· K^{-1}	
3. *Only one*solidus may be used in any combination.	m/s^2; m · kg/(s^3· A)	NOT: m/s/s NOT: m · kg/s^3/A
4. DO NOT USE the abbreviation ″p″ for ″per″ in the expression of a division.	km/h	NOT: kph *or* k.p.h.
5. Where the denominator is a product, this should be shown in parentheses.	W/(m^2· K)	

9.3 *Volume and Fluid Capacity*:

9.3.1 The preferred unit for measurement of volume in construction and for large storage tank capacities is the cubic metre (m^3).

9.3.2 The preferred units for measurement of fluid capacity (liquid volume) are the litre (L) and the millilitre (mL).

9.3.3 By international definition, the litre is equal to one thousandth of a cubic metre or one cubic decimetre (dm^3). (1 L = 10^{-3} m^3); (1 L = 1 dm^3); (1 m^3= 1000 L).

9.3.4 Because the cubic metre contains one billion (10^9) cubic millimetres, the cubic decimetre (dm^3) and the cubic centimetre (cm^3) may find limited application, particularly as they represent preferred steps of 1000 in volume measurement. It is suggested that any such cases be converted to preferred units for volume measurement as shown in Table 13.

9.4 *Geometrical Cross-Sectional Properties*:

9.4.1 The expression of geometrical cross-sectional properties of structural sections involves raising the unit of length to the third, fourth, or sixth power. Values can be shown either in mm^3, mm^4, or mm^6 with exponential notation, or in m^3, m^4, or m^6, with exponential notation.

9.4.2 The following are appropriate measurement units:

9.4.2.1 Modulus of section:

mm^3 or m^3(1 mm^3= 10^{-9} m^3);

9.4.2.2 Second moment of area or torsional constant:

mm^4 or m^4(1 mm^4= 10^{-12} m^4);

9.4.2.3 Warping constant:

mm^6 or m^6(1 mm^6= 10^{-18} m^6).

9.4.3 The cross-sectional properties of a wide-flange beam, 460 mm deep with 82 kg/m mass per unit length, could be expressed as follows:

9.4.3.1 Plastic modulus, Z_x

$= 1.835 \times 10^6$ mm^3 or 1.835×10^{-3} m^3;

9.4.3.2 Second moment of area, $I_{x—x}$

$= 0.371 \times 10^9$ mm^4 or 0.371×10^{-3} m^4;

9.4.3.3 Torsional constant, J

$= 0.691 \times 10^6$ mm^4 or 0.691×10^{-6} m^4;

9.4.3.4 Warping constant, C_w

$= 0.924 \times 10^{12}$ mm^6 or 0.924×10^{-6} m^6.

9.5 *Plane Angle*:

9.5.1 While the SI unit for plane angle, the radian (rad), should be used in calculations for reasons of its coherence, the customary units of angular measure, degree (°), minute (′), and second (”) of arc are likely to continue to be used in many applications in cartography and surveying.

9.5.2 The degree (°), with parts denoted by decimals (as in 27.25°), is likely to be utilized in engineering and in construction.

9.6 *Time Interval*:

9.6.1 In general applications, the day (d), hour (h), and minute (min) are permitted non-SI alternatives to the SI base unit for time, the second.

TABLE 6 Presentation of Numerical Values with SI

	Typical Examples	Remarks
A. *Decimal Marker*		
1. Whereas most European countries use the comma on the line as the decimal marker and this practice is advocated by ISO, a special exception is made for documents in the English language which have traditionally used the point (dot) on the line, or period, as decimal marker.		See also under G.
2. The recommended decimal marker for use in the United States is the point on the line (period), and the comma should not be used.	9.9; 15.375	NOT: 9,9; 15,375
3. *Always* show a zero before the decimal point for all numbers smaller than 1.0 (one).	0.1; 0.725	NOT: .1; .725
B. *Spacing*		
1. *Always* leave a gap between the numerical value associated with a symbol and the symbol, of at least half a space in width.	900 MHz; 200 mg; 10^6 mm^2 or 10^6 mm^2	NOT: 900MHz; 200mg NOT: 10^6mm^2
In the case of the symbol for the “degree Celsius” this space is optional, but the degree symbol must always be attached to C.	20°C or 20 °C	NOT: 20° C
2. In non-SI expressions of plane angle (°, ′, ″), DO NOT LEAVE A SPACE between the numerical value and the symbol.	27°30′ (of arc)	NOT: 27 ° 30 ′
3. *Always* leave a space on each side of signs for multiplication, division, addition, and subtraction	100 mm × 100 mm; 36 MPa + 8 MPa	NOT: 100 mm×100 mm NOT: 36 MPa + 8 MPa
C. *Fractions*		
1. *Avoid* common fractions in connection with SI units.	WRITE: 0.5 kPa	NOT: ½ kPa
2. *Always* use decimal notation to express fractions of any number larger than 1.0 (one).	1.5; 16.375	NOT: 1-½; 16-⅜

TABLE 6 *Continued*

	Typical Examples	Remarks
3. While the most common fractions such as half, third, quarter, and fifth will remain in speech, *always* show decimal notation in written, typed, or printed material.	0.5; 0.33; 0.25; 0.2	NOT: ½; ⅓; ¼; ⅕
D. *Powers of Units and Exponential Notation*		
1. When writing unit names with a modifier "squared" or "cubed," the following rules should be applied:		
a. In the case of area and volume, the modifier is written before the unit name as "square" and "cubic."	cubic metre; square millimetre	NOT: metre cubed; millimetre squared
b. In all other cases, the modifier is shown after the unit name as "squared," "cubed,"" to the fourth power,"etc.	metre per second squared	NOT: metre per square second; (or "metre per second per second")
c. The abbreviations" sq." for "square," and" cu." for "cubic" should *not* be used.		NOT: sq. millimetre NOT: cu. metre
2. For unit symbols with modifiers (such as square, cubic, fourth power, etc.) *always* show the superscript immediately after the symbol.	m^2; mm^3; s^4	NOT: m^2; mm^3; s^4
3. Show the superscript as a reduced size numeral raised half a line space. Where a typewriter without superscript numerals is used, the full size numeral should be raised half a line space, provided that this does not encroach on print in the line above.	mm^3, m/s^2	PERMITTED: mm^3, m/s^2
4. Where an exponent is attached to a prefixed symbol, it indicates that that multiple (or submultiple) is raised to the power expressed by the exponent.	$1\ mm^3 = (10^{-3}\ m)^3 = 10^{-9}\ m^3$ $1\ km^2 = (10^3\ m)^2 = 10^6\ m^2$	NOT: $1\ mm^3 = 10^{-3}\ m^3$
E. *Ratios*		
1. Do not mix units in expressing a ratio of like unit quantities.	0.01 m/m 0.03 m^2/m^2	NOT: 10 mm/m NOT: 30 000 mm^2/m^2
2. Wherever possible, use a non-quantitative expression (ratio or percentage) to indicate measurement of slopes, deflections, etc.		PREFERRED: 1:100; 0.01; 1 % 1:33; 0.03; 3 %
F. *Range*		
1. The choice of the appropriate prefix to indicate a multiple or submultiple of an SI unit is governed by convenience to obtain numerical values within a practical range and to eliminate nonsignificant digits.		
2. In preference, use prefixes representing ternary powers of 10 (10 raised to a power which is a multiple of 3).	milli, kilo, mega	AVOID: centi, deci, deka, hecto
3. Select prefixes so that the numerical value or values occur in a common range between 0.1 and 1000.	120 kN 3.94 mm 14.5 MPa	INSTEAD OF: 120 000 N 0.003 94 m 14 500 kPa
4. Compatibility with the general range must be a consideration; for example, if all dimensions on a drawing are shown in millimetres (mm), a range from 1 to 99 999 (a maximum of five numerals) would be acceptable to avoid mixing of units.		NOTE: Drawings should show "All dimensions shown in millimetres un- less otherwise noted".
G. *Presentation and Tabulation of Numbers*		
1. In numbers with many digits it has been common practice in the United States to separate digits into groups of three by means of commas. This practice must *not* be used with SI, to avoid confusion. It is recommended international practice to arrange digits in long numbers in groups of three from the decimal marker, with a gap of not less than half a space, and not more than a full space, separating each group.	54 375.260 55 54 375.260 55	NOT: 54,375.260,55 NOT: 54375.26055
2. For individual numbers with four digits before (or after) the decimal marker this space is not necessary.	4500; 0.0355	
3. In all tabulations of numbers with five or more digits before or after the decimal marker or both, group digits into groups of three: For example, 12.5255; 5735; 98 300; 0.425 75	12.525 5 5 735 98 300 0.425 75 104 047.951 25	