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An American National Standard

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.

ε1 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. 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.

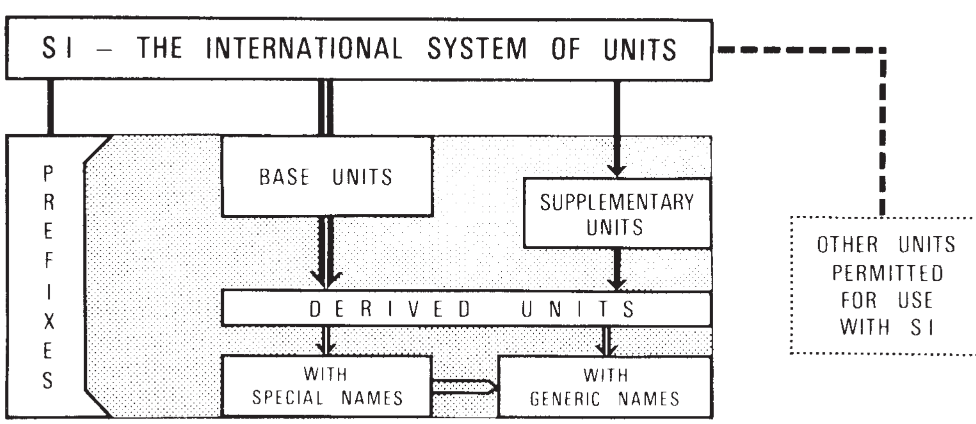
2.1.3 *unit*—reference value of a given quantity as defined by CGPM Resolution or ISO Standards. There is *only one* unit for each quantity in SI.

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.



[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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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	$kg{\cdot}m/s^2$	$m{\cdot}kg{\cdot}s^{-2}$	
	Pressure, stress, elastic modulus	pascal	Pa	N/m^2	$m^{-1}{\cdot}kg{\cdot}s^{-2}$	
	Energy, work, quantity of heat	joule	J	N·m	$m^2{\cdot}kg{\cdot}s^{-2}$	
	Power, radiant flux	watt	W	J/s	$m^2{\cdot}kg{\cdot}s^{-3}$	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	$m^2{\cdot}kg{\cdot}s^{-3}{\cdot}A^{-1}$	Already in common use
	Electric capacitance	farad	F	C/V	$m^{-2}{\cdot}kg^{-1}{\cdot}s^4{\cdot}A^2$	Already in common use
	Electric resistance	ohm	Ω	V/A	$m^2{\cdot}kg{\cdot}s^{-3}{\cdot}A^{-2}$	Already in common use
	Electric conductance	siemens	S	A/V or l/Ω	$m^{-2}{\cdot}kg^{-1}{\cdot}s^3{\cdot}A^2$	The ′siemens′ was formerly referred to as "mho."
	Magnetic flux	weber	Wb	V·s	$m^2{\cdot}kg{\cdot}s^{-2}{\cdot}A^{-1}$	Already in common use
	Magnetic flux density	tesla	T	Wb/m^2	$kg{\cdot}s^{-2}{\cdot}A^{-1}$	Already in common use
	Electric inductance	henry	H	Wb/A	$m^2{\cdot}kg{\cdot}s^{-2}{\cdot}A^{-2}$	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	$m^{-2}{\cdot}cd{\cdot}sr$	
	Activity (of a radionuclide)	becquerel	Bq	l/s	s^{-1}	No application in construction.
	Absorbed dose	gray	Gy	J/kg	$m^2{\cdot}s^{-2}$(*)	(*) 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}	
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.

TABLE 1 *Continued*

Unit Group	Quantity	Unit Name	Symbol	Formula	Unit Derivation	Remarks
	Moment of inertia	kilogram metre squared	kg·m^{2}		m^{2}·kg	
	Mass flow rate	kilogram per second	kg/s		kg·s^{-1}	
	Momentum	kilogram metre per second	kg·m/s		m·kg·s^{-1}	
	Angular momentum	kilogram metre squared per second	kg·m^{2}/s		m^{2}·kg·s^{-1}	
	Magnetic field strength	ampere per metre	A/m		m^{-1}·A	
	Current density	ampere per square metre	A/m^{2}		m^{-2}·A	
	Luminance	candela per square metre	cd/m^{2}		m^{-2}·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}·kg·s^{-2}	
	Flexural rigidity	newton square metre	N·m^{2}		m^{3}·kg·s^{-2}	
	Force per unit length, surface tension	newton per metre	N/m		kg·s^{-2}(1)	(1) m is canceled out
	Dynamic viscosity	pascal second	Pa·s		m^{-1}·kg·s^{-1}	
	Impact ductility	joule per square metre	J/m^{2}		kg·s^{-2} (2)	(2) m^{2} is canceled out
	Combustion heat (per unit volume)	joule per cubic metre	J/m^{3}		m^{-1}·kg·s^{-2}	
	Combustion heat (per unit mass), specific energy, specific latent heat	joule per kilogram	J/kg		m^{2}·s^{-2}(3)	(3) kg is canceled out
	Heat capacity, entropy	joule per kelvin	J/K		m^{2}·kg·s^{-2}·K^{-1}	
	Specific heat capacity, specific entropy	joule per kilogram kelvin	J/(kg·K)		m^{2}·s^{-2}·K^{-1} (4)	(4) kg is canceled out
	Heat flux density, irradiance, sound intensity	watt per square metre	W/m^{2}		kg·s^{-3} (5)	(5) m^{2} is canceled out
	Thermal conductivity	watt per metre kelvin	W/(m·K)		m·kg·s^{-3}·K^{-1}	(6) m^{2} is canceled out
	Thermal conductance	watt per square metre kelvin	W/(m^{2}·K)		kg·s^{-3}·K^{-1}(6)	
	Thermal resistance	square metre kelvin per watt	K·m^{2}/W		kg^{-1}·s^{3}·K (7)	(7) m^{2} is canceled out
	Electric field strength	volt per metre	V/m		m·kg·s^{-3}·A^{-1}	
	Electric flux density	coulomb per square metre	C/m^{2}		m^{-2}·s·A	
	Electric charge density	coulomb per cubic metre	C/m^{3}		m^{-3}·s·A	
	Electric permittivity	farad per metre	F/m		m^{-3}·kg^{-1}·s^{4}·A^{2}	
	Electric permeability	henry per metre	H/m		m·kg·s^{-2}·A^{-2}	
	Electric resistivity	ohm metre	Ω·m		m^{3}·kg·s^{-3};·A^{-2}	
	Electric conductivity	siemens per metre	S/m		m^{-3}·kg^{-1}·s^{3}·A^{2}	
	Light exposure	lux second	lx·s		m^{-2}·s·cd·sr	
	Luminous efficacy	lumen per watt	lm/W		m^{-2}·kg^{-1}·s^{3}·cd·sr	
d. *Units Expressed in Terms of Supplementary Units and Base and/or Derived Units:*						
	Angular velocity	radian per second	rad/s		s^{-1}·rad	
	Angular acceleration	radian per second squared	rad/s^{2}		m^{-2}·rad	
	Radiant intensity	watt per steradian	W/sr		m^{2}·kg·s^{-3}·sr^{-1}	
	Radiance	watt per square metre steradian	W/(m^{2}·sr)		kg·s^{-3}·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 $\times$ 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 Name	Prefix Symbol	Pronunciation
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 $10\frac{11}{16}$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 $3\frac{5}{16}$ 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
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*		

TABLE 5 *Continued*

	Typical Examples	Remarks
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 ppefix.	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; $W/(m \cdot K)$	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)	$kg \cdot m^{-3}$; $W \cdot m^{-1} \cdot K^{-1}$	
3. *Only one* solidus may be used in any combination.	m/s^2; $m \cdot kg/(s^3 \cdot A)$	NOT: m/s/s NOT: $m \cdot kg/s^3/A$
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.	$W/(m^2 \cdot K)$	

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:

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

9.4.2.2 Second moment of area or torsional constant:

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

9.4.2.3 Warping constant:

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

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

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

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

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

9.4.3.3 Torsional constant, J

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

9.4.3.4 Warping constant, C_w

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

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
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:		

TABLE 6 *Continued*

	Typical Examples	Remarks
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	
H. *Use of Unprefixed Units in Calculations*		
Errors in calculations involving compound units can be minimized if all prefixed units are reverted back to coherent base or derived units, with numerical values expressed in powers-of-ten notation.	PREFERRED: $136\ kJ = 136 \times 10^3\ J$ $20\ MPa = 20 \times 10^6\ Pa$ $1.5\ t\ (Mg) = 1.5 \times 10^3\ kg$	ALSO ACCEPTABLE: (or 1.36×10^5 J) (or 2×10^7 Pa)

9.6.2 It is recommended that the minute (min) be avoided as far as possible to minimize the variety of units in which time is a dimension.

9.6.3 For instance, *flow rates* should be expressed in cubic metres per second, litres per second, or cubic metres per hour, rather than in cubic metres per minute or litres per minute. For example:

1 m^3/s = 1000 L/s	(DO NOT USE 60 m^3/min)
1 L/s = 3.6 m^3/h	(DO NOT USE 60 L/min)
1 m^3/h = 1000 L/h	(DO NOT USE 16.67 L/min)

9.6.4 Because of its variability, the month should not be used to indicate a time dimension, unless a specific calendar month is referred to.

9.6.5 Where the calendar year (symbol "a") is used as a measurement for time interval, it represents 365 days or 31 536 000 s.

9.7 *Temperature and Temperature Interval*:

9.7.1 The SI base unit of (thermodynamic) temperature is the kelvin (K), and this unit is used for expressing both thermodynamic temperature and temperature interval.

9.7.2 Wide use is also made of the degree Celsius (°C) for the expression of ambient temperature levels in Celsius temperature and temperature intervals.

9.7.3 The temperature interval of one degree Celsius equals exactly one kelvin. For this reason, the degree Celsius (°C) may be used instead of the kelvin in calculations involving temperature interval.

9.7.4 A temperature expressed in degrees Celsius is equal to the temperature expressed in kelvins less 273.15. There are no negative (minus) temperature values in the kelvin scale.

9.7.5 The degree Celsius (°C) for Celsius temperature has been included in the table of derived SI units with special names approved by CIPM in 1976.

9.8 *Mass, Weight, and Force*:

9.8.1 A significant feature of SI is the use of explicit and distinctly separate units for "mass" and for "force."

TABLE 7 Electricity and Magnetism

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
Length (m)	m		metre	*Architecture and General Engineering:* Levels, overall dimensions, spans, column heights, etc., in engineering computations *Estimating and Specification:* Trenches, curbs, fences, lumber lengths, pipes and conduits; lengths of building materials generally *Land Surveying:* Boundary and cadastral surveys; survey plans; heights, geodetic surveys, contours *Hydraulic Engineering:* Pipe and channel lengths; depth of storage tanks or reserviors; height of potentiometric head, hydraulic head, piezometric head	Use metres on all drawings with scale ratios between 1:200 and 1:2000. Where required for purposes of accuracy, show dimensions to three decimal places.
	mm		millimetre	*Architecture and General Engineering:* Spans, dimensions in buildings, dimensions of buildings products; depth and width of sections; displacement, settlement, deflection, elongation; slump of concrete, size of aggregate; radius of gyration, eccentricity; detailed dimensions generally; rainfall *Estimating and Specification:* Lumber cross sections; thicknesses, diameters, sheet metal gages, fasteners; all other building product dimensions *Hydraulic Engineering:* Pipe diameters; radii of ground water wells; height of capillary rise; precipitation, evaporation	Use millimetres on drawings with scale ratios between 1:1 and 1:200. Avoid the use of centimetres (cm). Where" cm" is shown in documents, such as for snow depth, body dimensions, or carpet sizes, etc., convert to "mm" or "m".
	km		kilometre	Distances for transportation purposes geographical or statistical applications in surveying; long pipes and channels	
	µm		micrometre	Thickness of coatings (paint, galvanizing etc.), thin sheet materials, size of fine aggregate	
Area (m^2)	m^2		square metre	*General Applications:* Small land areas; area of cross section of earthworks, channels and larger pipes; surface area of tanks and small reservoirs; areas in general	(1 m^2 = 10^6 mm^2)
				Estimating and Specification: Site clearing; floor areas; paving, masonry construction, roofing, wall and floor finishes,	Replaces sq. ft.; sq. yd., and square. Specify masonry construction by

TABLE 7 *Continued*

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
				plastering, paintwork, glass areas, membranes, lining materials, insulation, reinforcing mesh, formwork; areas of all building components	wall area × wall thickness.
	mm^2		square millimetre	Area of cross section for structural and other sections, bars, pipes, rolled and pressed shapes, etc.	Avoid the use of cm^2(square centimetre) by conversion to mm^2. ($1\ cm^2 = 10^2\ mm^2 = 100\ mm^2$)
	km^2		square kilometre	Large catchment areas or land areas	
		ha	hectare	Land areas; irrigation areas; areas on boundary and other survey plans	($1\ ha = (10^2\ m)^2 = 10^4\ m^2 = 10\ 000\ m^2$)
Volume, Capacity (m^3)	m^3		cubic metre	*General Applications:* Volume, capacity (large quantities); volume of earthworks, excavation, filling, waste removal; concrete, sand, all bulk materials timber timber *Hydraulic Engineering:* Water distribution, irrigation, diversions, sewage, storage capacity, underground basins	$1\ m^3 = 1000\ L$ As far as possible, use the cubic metre as the preferred unit of volume for engineering purposes.
	mm^3		cubic millimetre	Volume, capacity (small quantities)	
		L	litre	Volume of fluids and containers for fluids; liquid materials, domestic water supply, consumption; volume/capacity of full tanks	The litre and its multiples or sub-multiples may be used for domestic and industrial supplies of liquids $1\ L = 1\ dm^3$
		mL	millilitre	Volume of fluids and containers for fluids (limited application only)	See Section 9.3
Modulus of Section (m^3)	mm^3		millimetre to third power	Geometric properties of structural sections, such as plastic section modulus, elastic section modulus, etc.	See Section 9.4
	m^3		metre to third power		
Second Moment of Area (m^4)	mm^4		millimetre to fourth power	Geometric properties o moment of inertia of a section, torsional constant of cross section	See Section 9.4
	m^4		metre to fourth power		
Plane Angle (rad)	rad		radian	Generally used in calculations only to preserve coherence	Slopes and gradients may be expressed as a ratio or as a percentage:
	mrad		milliradian	*General Applications:*	
		(–°)	degree (of arc)	Angular measurement in construction generally; angle of rotation, torsion, shear resistance, friction, internal friction, etc. (decimalized degrees) *Land Surveying:* Bearings shown on boundary and cadastral survey plans; geodetic surveying	26.57° = 1:2 = 50% = 0.4637 rad (1 rad = 57.2958°) See Section 9.5
Time, Time Interval, Duration (s)	s		second	Time used in test methods; all calculations involving derived units with a time component, in order to preserve coherence	Avoid the use of minute (min) as far as possible
		h	hour	Time used in test methods, all calculations involving labor time, plant hire, maintenance periods, etc.	(1 h = 3600 s)
		d	day		(1 d = 86 400 s) = 86.4 ks)
		a	year (annum)		
Frequency (Hz)	Hz		hertz	Frequency of sound, vibration, shock	($1\ Hz = l/s = s^{-1}$) Replaces cycle per second (c/s or cps) See also Table 11.
	kHz		kilohertz		
	MHz		megahertz		
Rotational Frequency, Speed of Rotation (s^{-1})		r/s	revolution per second	Widely used in the specification of rotational speed of machinery Use r/min *only* for slow-moving equipment.	($1\ r/s = 2\ \pi\ rad/s$)
Velocity, Speed (m/s)	m/s		metre per second	Calculations involving rectilinear motion, velocity and speed in general; wind velocity;	(1 m/s = 3.6 km/h)

TABLE 7 *Continued*

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
				velocity of fluids; pipe flow velocity	
		km/h	kilometre per hour	Wind speed; speed used in transportation; speed limits	
		mm/h	millimetre per hour	Rainfall intensity	
Angular Velocity (rad/s)	rad/s		radian per second	Calculation involving rotational motion	
Linear Acceleration (m/s^2)	m/s^2		metre per second squared	Kinematics and calculation of dynamic forces	Recommended value of acceleration of gravity for use in U.S.: g_{us} = 9.8 m/s^2
Volume Rate of Flow (m^3/s)	m^3/s	m^3n	cubic metre per second cubic metre per hour	Volumetric flow in general; flow in pipes, ducts, channels, rivers, irrigation spray demand	(1 m^3/s = 1000 L/s)
		m^3/d	cubic metre per day		
		L/s	litre per second	Volumetric flow of fluids only	
		L/d	litre per day		

9.8.2 The SI base unit *kilogram* (kg) denotes the *base unit of mass* (the unit quantity of matter of an object which is constant and independent of gravitational attraction).

9.8.3 The derived SI unit *newton* (N) denotes the *absolute derived unit of force* (mass times acceleration: kg · m/s^2).

9.8.4 The general use of the term "weight" should be avoided in technical practice for the following reasons:

9.8.4.1 Considerable confusion exists because the term" weight" has been used to mean either "mass" or "force of gravity."

9.8.4.2 In commercial and everyday use, the term "weight" has nearly always meant mass.

9.8.4.3 In technical use, the term "weight" has often been applied to mean "force of gravity," a *particular force,* related solely to gravitational acceleration, which varies on the surface of the earth.

9.8.4.4 Where quantities are shown as "weight" it is important to establish whether "mass" or "force" is intended, and to use the appropriate SI units, that is, kilogram for "mass" and newton for "force."

9.8.5 As serviceable as customary gravitational systems may seem in the area of "statics," the absolute and more universally useful concepts of the clear SI distinction between "mass" and" force" will become increasingly significant as engineering and construction become more and more involved in "dynamic" considerations.

9.8.6 In dynamic calculations, the value of a mass in kilograms (kg) is used directly with the appropriate acceleration to determine force, the applicable equation being $F = ma$. The frequently used equation $W = mg$, in which W is considered to equal "weight" should be superseded (see 9.8.4) by $F_g = mg$, in which F_g is the force of gravity.

TABLE 8 Mechanics: Statics and Dynamics

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
Mass (kg)	kg		kilogram	Mass of materials in general, mass of structural elements and machinery	USE kilograms (kg) in calculations and specifications
	g		gram	Mass of samples of material for testing	Masses greater than 10^4 kg (10 000 kg) may be conveniently expressed in metric tons (t):
		t	metric ton	Mass of large quantities of materials, such as structural steel, reinforcement, aggregates, concrete, etc.; ratings of lifting equipment	1 t = 10^3 kg = 1 Mg = 1000 kg
Mass per Unit Length (kg/m)	kg/m		kilogram per metre	Mass per unit length of sections, bars, and similar items of uniform cross section	Also known as "linear density"
		g/m	gram per metre	Mass per unit length of wire and similar material of uniform cross section	
Mass per Unit Area (kg/m^2)	kg/m^2		kilogram per square metre	Mass per unit area of slabs, plates, and similar items of uniform thickness or depth; rating for load-carrying capacities on floors (display on notices only)*	*DO NOT USE in stress calculations
		g/m^2	gram per square metre	Mass per unit area of thin sheet materials, coatings, etc.	
Mass Density, Concentration (kg/m^3)	kg/m^3		kilogram per cubic metre	Density of materials in general; mass per unit volume of materials in a concrete mix; evaluation of masses of structures and materials	Also known as "mass per unit volume"
		g/m^3	gram per cubic metre	Mass per unit volume (concentration) in pollu-	

TABLE 8 *Continued*

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
				tion control	
		μg/m^3	microgram per cubic metre		
Momentum (kg·m/s)	kg·m/s		kilogram metre per second	Used in applied mechanics; evaluation of impact and dynamic forces	
Moment of Inertia (kg·m^2)	kg·m^2		kilogram square metre	Rotational dynamics. Evaluation of the restraining forces required for propellers, windmills, etc.	See also Section 9.10.5
Mass per Unit Time (kg/s)	kg/s		kilogram per second	Rate of transport of material on conveyors and other materials handling equipment	1 kg/s = 3.6 t/h
		t/h	metric ton per hour		
Force (N)	N		newton	Unit of force for use in calculations	1 N = 1 kg·m/s^2
	kN		kilonewton	Forces in structural elements, such as columns, piles, ties, pre-stressing tendons, etc.; concentrated forces; axial forces; reactions; shear force; gravitational force	See also Section 9.8
Force per Unit Length (N/m)	N/m		newton per metre	Unit for use in calculations	
	kN/m		kilonewton per metre	Transverse force per unit length on a beam, column, etc.; force distribution in a linear direction	
Moment of Force, Torsional or Bending Moment, Torque (N · m)	N · m kN · m MN · m		newton metre kilonewton metre meganewton metre	Bending moments (in structural sections), tor sional moment; overturning moment; tightening tension for high-strength bolts; torque in engine drive shafts, axles, etc.	See also Sections 9.10.4 and 9.10.5
Pressure, Stress, Modulus of Elasticity (Pa)	Pa		pascal	Unit for use in calculations; low differential pressure in fluids; duct pressure in air conditioning, heating, and ventilating systems	(1 Pa = 1 N/m^2)
	kPa		kilopascal	Uniformly distributed pressure (loads) on floors; soil bearing pressure; wind pressure (loads), snow loads, dead and live loads; pressure in fluids; fluid flow resistance in closed systems; differential pressure in high-pressure ventilation systems	Where wind pressure, snow loads, dead and live loads are shown in kN/m^2, CHANGE units to kPa
	MPa		megapascal	Modulus of elasticity; stress (ultimate, proof, yield, permissible, calculated, etc.) in structural materials; concrete and steel strength grades	1 MPa = 1 MN/m^2 = 1 N/mm^2
	GPa		gigapascal	Modulus of elasticity in high-strength materials	
	μPa		micropascal	Sound pressure (20 μPa is the reference quan tity for sound pressure level)	
Compressibility (Pa^{-1})	1/Pa		reciprocal (of) pascal	Settlement analysis, coefficient of compressibility, bulk compressibility	(1/Pa = 1 m^2/N)
	1/kPa		reciprocal (of) kilopascal		
Dynamic Viscosity (Pa · s)	Pa·s mPa·s		pascal second millipascal second	Shear stresses in fluids	(1 Pa·s = 1 N·s/m^2) The centipoise (cP) = 10^{-3} Pa·s WILL NOT BE USED
Kinematic Viscosity (m^2/s)	m^2/s		square metre per second		The centistokes (cSt) = 10^{-6} m^2/s WILL NOT BE USED
	mm^2/s		square millimetre per second	Computation of Reynold's number, settlement analysis (coefficient of consolidation)	1 cSt = 1 mm^2/s
Work, Energy (J)	J kJ MJ		joule kilojoule megajoule	Energy absorbed in impact testing of materials; energy in general; calculations involving mechanical and electrical energy	
		kWh	kilowatthour	Electrical energy applications only	1 kWh = 3.6 MJ
Impact Strength (J/m^2)	J/m^2		joule per square metre	Impact strength; impact ductility	
	kJ/m^2		kilojoule per square metre		
Power (W)	W kW		watt kilowatt	Power in general (mechanical, electrical, thermal); input/output rating, etc., of motors,	

TABLE 8 *Continued*

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
				engines, heating and ventilating plant, and other equipment in general	
	MW		megawatt	Power input/output rating, etc., of heavy power plant	
	pW		picowatt	Sound power level (1 pW is the reference quantity for sound power level)	

9.8.7 For engineering design purposes, in United States locations the recommended value to be used for acceleration of gravity is: $g = 9.8$ m/s^2. (The standard international value is 9.806 65.)

9.8.8 The use of the factor 9.8 (m/s^2) is recommended for *g* because:

9.8.8.1 It provides adequate accuracy in nearly all instances,

9.8.8.2 It gives fewer decimal places than the use of 9.81 or 9.806 65 which was advocated in Britain, and

9.8.8.3 It provides a different number in the product than would be obtained with the use of a factor of 10 (advocated by some), which can be easily overlooked and cause errors.

9.8.9 The newton extends through to derived quantities for pressure and stress, energy, work and quantity of heat, power, and many of the electrical units.

9.8.10 The unit kilogram-force (kgf) is inconsistent with SI, and is in the process of being dropped and replaced by the newton in traditionally metric countries. The kilogram-force (kgf) should *not* be used in the United States.

9.9 *Pressure, Stress, and Elastic Modulus*:

9.9.1 The SI unit for both pressure and stress (force per unit area) is the pascal (Pa). It replaces a large number of customary units and also supersedes a few traditional but non-SI metric units.

9.9.2 While it may be useful in some applications to read out test results in N/mm^2 (which is identical with MN/m^2), or in kN/m^2, it is preferable and recommended always to show calculations and results in MPa or kPa.

9.9.3 The non-SI units, the "bar" (which equals 100 kPa or 0.1 MPa) and the "millibar" (which equals 100 Pa or 0.1 kPa) should *not* be used.

9.10 *Energy, Work, and Quantity of Heat*:

9.10.1 The SI unit of energy, work, and quantity of heat is the joule (J), which is equal to a newton metre (N·m) and a watt second (W·s).

9.10.2 The joule provides one coherent unit to supersede a large number of traditional units: Btu, therm, calorie, kilocalorie, foot pound-force, etc.

9.10.3 For many years, and since long before the joule was named, the kilowatthour (kWh) (Note 3) has been used extensively as the unit of energy in electrical energy consumption. Most existing electricity meters show kWh, and recalibration in megajoules (MJ) would be needlessly costly. For this reason, the kWh will be permitted as an alternative unit in electrical applications, but should not be introduced in new areas.

NOTE 3—The accepted symbol in the United States is "kWh," but the correct SI symbol would be kW·h.

9.10.4 The joule should *never* be used for torque for which the widely designated unit is newton metre (N·m).

9.10.5 For dimensional consistency in rotational dynamics, torque should be expressed as newton metre per radian (N·m/rad), and moment of inertia as kilogram square metre per radian squared (kg·m^2/rad^2).

9.11 *Power and Heat Flow Rate*:

9.11.1 The SI unit for power and heat flow rate is the watt (W), which is already in world-wide use as the general unit for electrical power.

9.11.2 The watt, and its multiples, will now replace a number of traditional units of power and heat flow rate:

9.11.2.1 For general power: the horsepower (electric, boiler) and the foot pound-force per hour (or minute or second)

9.11.2.2 For heat flow rate: the Btu per hour and the calorie (or kilocalorie) per minute (or second); the ton of refrigeration

TABLE 9 Heat, Thermal Effects, Heat Transfer

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
Temperature Value (K)	K		kelvin	Expression of thermodynamic temperature; calculations involving units of temperature	(t°C = T_K − 273.15)
		°C	degree Celsius	Common temperature scale for use in applications; meteorology and general ambient temperature values	Temperature values will normally be measured in °C (degrees Celsius)
Temperature Interval (K)	K		kelvin	Heat transfer calculations; temperature intervals in test methods, etc.	(1 K = 1°C) The use of K (kelvin) in compound units is recommended
		°C	degree Celsius		

TABLE 9 *Continued*

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Accept-able Units	Unit Name	Typical Applications	Remarks
Coefficient of Linear Thermal Expansion (1/K)	1/K		reciprocal (of) kelvin	Expansion of materials subject to a change in temperature (generally expressed as a ratio per kelvin or degree Celsius)	
		1/°C	reciprocal (of) degree Celsius		
Heat, Quantity of Heat (J)	J		joule	Thermal energy calculations. Enthalpy, latent heat, sensible heat	
	kJ		kilojoule		
	MJ		megajoule		
Specific Energy, Specific Latent Heat; Combustion Heat (mass basis) (J/kg)	J/kg		joule per kilogram	Heat of transition; heat and energy contained in materials; combustion heat per unit mass; calorific value of fuels (mass basis); specific sensible heat, specific latent heat in psychrometric calculations	
	kJ/kg		kilojoule per kilogram		
	MJ/kg		megajoule per kilogram		
Energy Density, Combustion Heat (volume basis) (J/m^3)	J/m^3		joule per cubic metre	Combustion heat per unit volume	
	kJ/m^3		kilojoule per cubic metre		(1 kJ/m^3 = 1 J/L)
	MJ/m^3		megajoule per cubic metre	Calorific value of fuels (volume basis)	(1 MJ/m^3 = 1 kJ/L)
Heat Capacity, Entropy (J/K)	J/K		joule per kelvin	Thermal behavior of materials, heat transmission calculations, entropy	
	kJ/K		kilojoule per kelvin		
Specific Heat Capacity, Specific Entropy (J/(kg·K))	J/(kg·K)		joule per kilogram kelvin	Thermal behavior of materials, heat transmission calculations	
	kJ/(kg·K)		kilojoule per kilogram kelvin		
Heat Flow Rate (W)	W		watt	Heat flow through walls, windows, etc.; heat demand	(1 W = 1 J/s)
	kW		kilowatt		
Power Density, Heat Flux, Density, Irradiance (W/m^2)	W/m^2		watt per square metre	Density of power or heat flow through building walls and other heat transfer surfaces; heat transmission calculations	
	kW/m^2		kilowatt per square metre		
Heat Release Rate (W/m^3)	W/m^3		watt per cubic metre	Rate of heat release per unit volume over time (for gases and liquids)	1 W/m^3 = 1 $J/(m^3·s)$
	kW/m^3		kilowatt per cubic metre		
Thermal Conductivity (W/(m·K))	W/(m·K)		watt per metre kelvin	Estimation of thermal behavior of homogeneous materials and systems; heat transmission calculations	1 W/(m·K) = 1 W/(m·°C) = 1 W.m/(m^2·K)
		W/(m·°C)	watt per metre degree Celsius	Thermal conductivity of structural and building materials in fire-resistance testing, insulation, etc.	(“*k*” value)
Thermal Conductance (W/(m^2·K))	W/(m^2·K)		watt per square metre kelvin	Heat transfer calculations for buildings, building components and equipment. Transmittance of construction elements; calculation of coefficients of heat transfer	(“*U*” value) In ISO 31/IV this quantity is called *coefficient of heat transfer*
		W/(m^2·°C)	watt per square metre degree Celsius		
	kW/(m^2·K)		kilowatt per square metre kelvin		
		kW/(m^2·°C)	kilowatt per square metre degree Celsius		
Thermal Resistivity ((m·K)/W)	(m·K)/W		metre kelvin per watt	Heat transmission calculations for materials and building elements (Reciprocal of thermal conductivity)	
		(m·°C)/W	metre degree Celsius per watt		
Thermal-Resistance ((m^2·K)/W)	(m^2·K)/W		square metre kelvin per watt	Heat transmission calculations; rating of thermal insulating materials (thermal resistances are additive)	(“*R*” value) In ISO 31/IV this quantity is called thermal insulance and the quantity thermal resistance has the unit K/W
		(m^2·°C)/W	square metre degree Celsius per watt		

9.12 *Moisture Movement in Buildings*:

9.12.1 Moisture vapor movement through materials and constructions is expressed by the quantities vapor permeance and vapor permeability. The word vapor should always be used to distinguish the quantities from permeance and permeability, which are used in the electro-magnetic field and have different meanings.

9.12.2 The traditional unit "perm" represents a specification of performance, the lower the "perm" value, the greater the retardation of moisture movement. The "metric perm" (g/(24 h·m^2·mmHg)) is a non-SI unit and should not be used.

9.12.3 Resistance to moisture movement is expressed by the quantities vapor resistance and vapor resistivity. Vapor resistances are additive so that the higher the vapor-resistance value, the better the resistance to moisture movement.

9.13 *Electrical Units*:

9.13.1 There are no changes in units used in electrical engineering, except

9.13.1.1 The renaming of the unit of conductance to siemens (S) from "mho."

9.13.1.2 The use of the SI unit for frequency, hertz (Hz), instead of cycles per second (cps).

9.14 *Lighting Units*:

9.14.1 The SI unit for luminous intensity, candela (cd), and for luminous flux, lumen (lm), are already in common use.

9.14.2 The candela (cd) directly replaces the former units "candle" and "candlepower."

9.14.3 Illuminance will be expressed in the SI unit lux (lx), which is equal to the lumen per square metre (lm/m^2), and replaces lumen per square foot and footcandle.

9.14.4 Luminance will be expressed in candela per square metre (cd/m^2), which replaces candela per square foot, footlambert, and lambert.

9.15 *Dimensionless Quantitites*—Dimensionless quantities, or ratios, such as relative humidity, specific gravity, decibel (dB), pH, parts per million, etc., remain unchanged when converting to SI.

9.16 *Constants for Use in Building Design Calculations*—Table 14 shows a selection of internationally agreed values and empirical constants for use in design calculations, taken to no more than six significant figures.

10. Conversion and Rounding

10.1 Rules for conversion and rounding are not covered by this standard. They are given in Section 5 of ASTM E380, Standard for Metric Practice.

10.2 Conversion factors for the conversion of the principal quantities in building design and construction are given in Appendix X1. A more detailed list of conversion factors, to six places of decimals and in exponential notation for ready adaptation in computer readout and electronic data transmission, is given in Appendix X3, Conversion Factors of ASTM E380.

10.3 In the conversion of data, the need for precision is determined by the legal requirements or by any requirement for the interchangeability of parts. To obtain a more convenient numerical expression, it will often be preferable to round an "exact conversion" within tolerances of the original value. This is termed a "soft conversion." The change to a new and non-interchangeable value based on preferred or convenient numbers is termed a "hard conversion" and generally involves a physical change in size or properties.

10.4 Guidance on preferred numbers and number series is contained in international standards ISO 3, ISO 17, and ISO 497, as well as in ANSI Z17.1. The selection of preferred metric values for design and construction is also discussed in NBS Technical Note 990.

TABLE 10 Moisture Movement

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
Mass (of Moisture Vapor) (kg)	mg µg ng		milligram microgram nanogram	Measurement of quantity of moisture vapor	
Vapor Pressure (Pa)	Pa		pascal	Measurement of vapor pressure, vapor pressure difference, vapor pressure drop	Do not use millibar (mbar) or millimetre of mercury (mmHg)
Vapor Permeance (kg/(Pa·s·m^2))	µg/(Pa·s·m^2) ng/(Pa·s·m^2)		microgram per pascal second square metre nanogram per pascal second square metre	Transmission of moisture vapor through building elements (roofs, walls, floors); surface coefficient of vapor transfer in still or moving air	In some countries, the SI unit kg/(N·s) is used for this quantity, with m^2 cancelled out. Vapor permeance is the reciprocal of vapor resistance
Vapor Permeability (kg/(Pa·s·m))	µg/(Pa·s·m) ng/(Pa·s·m)		microgram per pascal second metre nanogram per pascal second metre	Transmission of moisture vapor through a specified thickness of a homogeneous material or construction	The unit has been reduced from . kg·m/(Pa·s·m^2). In some countries kg·m/(N·s) is used Vapor permeability is the reciprocal of vapor resistivity
Vapor Resistance (Pa·s·m^2/kg)	MPa·s·m^2/kg GPa·s·m^2/kg		megapascal second square metre per kilogram gigapascal second square metre per kilogram	Resistance to moisture vapor transmission by building elements; surface vapor resistance in still or moving air	
Vapor Resistivity (Pa·s·m/kg)	MPa·s·m/kg GPa·s·m/kg		megapascal second metre per kilogram gigapascal second metre per kilogram	Resistivity to moisture vapor transmission by a specified thickness of a homogeneous material or construction	Vapor resistivities are additive

TABLE 11 Electricity and Magnetism

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
Frequency (Hz)	Hz		hertz	Frequencies of electromagnetic waves; power frequency for electric motors; radio frequencies	1 Hz = 1/s = s^{-1} Replaces cycle per second (c/s or cps) See also Table 7
	kHz		kilohertz		
	MHz		megahertz		
Electric Current (A)	A		ampere	Maintenance rating of an electrical installation. Leakage current	
	kA		kiloampere		
	mA		milliampere		
	µA		microampere		
Magnetomotive Force, Magnetic Potential Difference (A)				Used in the calculations involved in magnetic circuits	
Magnetic Field Strength, Magnetization (A/m)	A/m		ampere per metre	Magnetic field strength is used in calculation of magnetic circuitry such as transformers, magnetic amplifiers, and general cores.	(1 kA/m = 1 A/mm)
	kA/m		kiloampere per metre		
Current Density (A/m^2)	A/m^2		ampere per square metre	Design of cross-sectional area of electrical conductor	
	kA/m^2		kiloampere per square metre		
		A/mm^2	ampere per square millimetre		(1 A/mm^2 = 1 MA/m^2)
Electric Charge, Quantity of Electricity (C)	C		coulomb	The voltage on a unit with capacitive-type characteristics may be related to the amount of charge present (for example, electrostatic precipitators). Storage battery capacities	1 C = 1 A·s DO NOT USE ampere hour: 1 A·h = 3.6 kC
	kC		kilocoulomb		
	µC		microcoulomb		
	nC		nanocoulomb		
	pC		picocoulomb		
Electric Potential, Potential Difference, Electromotive Force (V)	V		volt		1 V = 1 W/A
	MV		megavolt		
	kV		kilovolt		
	mV		millivolt		
	µV		microvolt		
Electric Field Strength (V/m)	V/m		volt per metre	The electric field strength gives the potential gradient at points in space. This may be used to calculate or test electrical parameters such as dielectric strength.	
	MV/m		megavolt per metre		
	kV/m		kilovolt per metre		
	mV/m		millivolt per metre		
	µV/m		microvolt per metre		
Active Power (W)	W		watt	The useful power of an electrical circuit is expressed in watts (W). (The apparent power in an electrical circuit is expressed in volt-amperes (V·A).)	1 W = 1 V·A
	GW		gigawatt		
	MW		megawatt		
	kW		kilowatt		
	mW		milliwatt		
	µW		microwatt		
Capacitance (F)	F		farad	Electronic components. Electrical design and performance calculators	1 F = 1 C/V
	mF		millifarad		
	µF		microfarad		
	nF		nanofarad		
	pF		picofarad		
Resistance (Ω)	Ω		ohm	The design of electrical devices with resistance, such as motors, generators, heaters, electrical distribution systems, etc.	1Ω = 1 V/A
	GΩ		gigaohm		
	MΩ		megohm		
	kΩ		kilohm		
	mΩ		milliohm		
Conductance, Admittance, Susceptance (S)	S		siemens		The siemens (S) was formerly known as "mho"
	MS		megasiemens		
	kS		kilosiemens		
	mS		millisiemens		
	µS		microsiemens		
Resistivity (Ω·m)	Ω·m		ohm metre		
	GΩ·m		gigaohm metre		
	MΩ·m		megohm metre		
	kΩ·m		kilohm metre		
	mΩ·m		milliohm metre		
	µΩ·m		microohm metre		

TABLE 11 *Continued*

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
	nΩ·m		nanoohm metre		
(Electrical) Conductivity (S/m)	S/m		siemens per metre	A parameter for measuring water quality	
	MS/m		megasiemens per metre		
	kS/m		kilosiemens per metre		
	µS/m		microsiemens per metre		
Magnetic Flux, Flux of Magnetic Induction (Wb)	mWb		milliweber	Used in the calculations involved in magnetic circuits	1 Wb = 1 V·s
Magnetic Flux Density, Magnetic Induction (T)	T mT µT nT		tesla millitesla microtesla nanotesla	Used in the calculations involved in magnetic circuits	1 T = 1 Wb/m^2
Magnetic Vector Potential (Wb/m^2)	kWb/m^2		kiloweber per square metre	Used in the calculations involved in magnetic circuits	
Self-Inductance, Mutual Inductance, Permeance (H)	H mH µH nH pH		henry millihenry microhenry nanohenry picohenry	Used in analysis and calculations involving transformers	1 H = 1 Wb/A
Reluctance (1/H)	1/H		reciprocal of henry	Design of motors and generators	
Permeability (H/m)	H/m µH/m nH/m		henry per metre microhenry per metre nanohenry per metre	Permeability gives the relationship between the magnetic flux density and the magnetic fluid strength.	

TABLE 12 Lighting

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
Luminous Intensity (cd)	cd		candela		
Solid Angle (sr)	sr		steradian		
Luminous Flux (lm)	lm klm		lumen kilolumen	Luminous flux of light sources, lamps and light bulbs	1 lm = 1 cd·sr Already in general use
Quantity of Light (lm·s)	lm·s	 lm·h	lumen second lumen hour		1 lm·h = 3600 lm/s
Luminance (cd/m^2)	cd/m^2 kcd/m^2	 cd/mm^2	candela per square metre kilocandela per square metre candela per square millimetre	Assessment of surface brightness; luminance of light sources, lamps and light bulbs; calculation of glare in lighting layouts	Replaces stilb (1 sb = 10^4 cd/m^2) and apostilb (1 apostilb = $cd/\pi m^2$)
Illuminance (lx)	lx klx		lux kilolux	Luminous flux per unit area is used in determination of illumination levels and design/evaluation of interior lighting layouts. (Outdoor daylight illumination on a horizontal plane ranges up to 100 klx.)	a) Formerly referred to as illumination 1 lx = 1 lm/m^2 b) Replaces phot (1 ph = 10^4 lx) c) Luminous exitance is described in lm/m^2
Light Exposure (lx·s)	lx·s klx·s		lux second kilolux second		
Luminous Efficacy (lm/W)	lm/W		lumen per watt	Rating of luminous efficacy of artificial light sources	

TABLE 13 Acoustics

Quantity (and SI Unit Symbol)	Preferred Units (Symbols)	Other Acceptable Units	Unit Name	Typical Applications	Remarks
Wavelength (m)	m mm		metre millimetre	Definition of sound wave pitch	
Area of Absorptive Sur face (m^2)	m^2		square metre	Surface areas in the calculation of room absorption	Absorptive properties of buildings and building materials have also been expressed in the non-SI unit "metric sabin"
Period, Periodic Time (s)	s ms		second millisecond	Measurement of time, reverberation time, and duration of sound	
Frequency (Hz)	Hz kHz		hertz kilohertz	Frequency bands or ranges in acoustical calculations and measurements; frequency of vibrations	1 Hz = 1/s = s^{-1} Replaces cycle per second (c/s or cps)
Sound Pressure (Pa)	Pa mPa		pascal millipascal	Measurement of instantaneous or peak sound pressure, normally expressed in root-mean-square (rms) values. The standard reference value for sound pressure is 20 µPa. Sound pressure levels are generally shown in the non-dimensional logarithmic unit decibel (dB) signifying the ratio of actual pressure to reference pressure.	Do NOT USE dyne (1 dyn = 10 µPa)
	µPa		micropascal	Sound pressure level $L_p = 20\log_{10}\frac{\text{actual pressure (Pa)}}{20 \times 10^{-6}\text{ (Pa)}}$	
Sound Power, Sound Energy Flux (W)	W mW µW		watt milliwatt microwatt	Measurement of sound power and rate of flow of sound energy. The standard reference value for sound power is 1 pW (10^{-12}W).	
	pW		picowatt	Sound power level, $L = 10\log_{10}\frac{\text{actual pressure (W)}}{20 \times 10^{-12}\text{ (W)}}$	
Sound Energy Density (J/m^3)	J/m^3		joule per cubic metre	Measurement of mean sound energy density	
Sound Intensity (W/m^2)	W/m^2		watt per square metre	Measurement of sound intensity	The standard reference value for sound intensity is 1 pW/m^2 ($10^{-12}W/m^2$)
	pW/m^2		picowatt per square metre	Sound intensity level L_I: $= 10\log_{10}\frac{\text{actual intensity }(W/m^2)}{10^{-12}\ (W/m^2)}$	
Specific Acoustic Impedance (Pa·s/m)	Pa·s/m		pascal second per metre	Sound impedance measurement	(1 Pa·s/m = 1 N·s/m^3)
Acoustic Impedance, Acoustic Resistance (Pa·s/m^3)	Pa·s/m^3		pascal second per cubic metre	Sound impedance measurement	

TABLE 14 Units for Volume and Fluid Capacity and Their Relationships

Preferred Units: All Volumes	Preferred Units: Fluid Volume Only	Limited Application	Relationships
m^3			1 m^3 = 1000 L = 1000 dm^3
	L	dm^3	1 L = 1 dm^3 = 10^{-3} m^3 = 1000 mL 10^6 mm^3
	mL	cm^3	1 mL = 1 cm^3 = 10^{-6} m^3 10^3 mm^3
mm^3			1 mm^3 = 10^{-9} m^3

TABLE 15 Constants for Use in Building Design Calculations

Name	Symbol	Value	Unit
Standard atmosphere pressure (international value)	P_o	101.325	kPa
Absolute (zero) temperature	T	0.0 (−273.15)	K (°C)
Velocity of sound in air (P_o, 20°C, 50 % relative humidity)	M	344	m/s
Specific volume of perfect gas at STP	V_o	22.414	m^3/kmol (L/mol)
Characteristic gas constant for air	R_a	287.045	J/(kg·K)
Characteristic gas constant for water vapor	R_v	461.52	J/(kg·K)

11. Keywords

11.1 building; construction; metric; metric units; SI units

APPENDIXES

(Nonmandatory Information)

X1. CONVERSION FACTORS FOR THE MOST COMMON UNITS USED IN BUILDING DESIGN AND CONSTRUCTION

X1.1 Where appropriate, conversion factors are taken to six significant figures. Underlined values denote exact conversions.

Metric to Customary			Customary to Metric		
			LENGTH		
1 km	= 0.621 371	mile (international)	1 mile (international)	= 1.609 344	km
1 m	= 49.7096	chain	1 chain (survey unit)	= 20.1168	m
	= 1.093 61	yd	1 yd	= 0.9144	m
	= 3.280 84	ft	1 ft	= 0.3048	m
1 mm	= 0.039 370 1	in		= 304.8	mm
			1 in	= 25.4	mm
		(	1 U.S. survey foot	= 0.304 800 6	m)*
* Section 9.1.7 deals with U.S. survey measurement.					
			AREA		
1 km^2	= 0.386 101	mile^2(U.S. survey)	1 mile^2(U.S. survey)	= 2.590 00	km^2
1 ha	= 2.471 04	acre (U.S. survey)	1 acre (U.S. survey)	= 0.404 687	ha
1 m^2	= 1.195 99	yd^2		= 4046.87	m^2
	= 10.7639	ft^2	1 yd^2	= 0.836 127	m^2
1 mm^2	= 0.001 550	in^2	1 ft^2	= 0.092 903	m^2
			1 in^2	= 645.16	mm^2
			VOLUME, MODULUS OF SECTION		
1 m^3	= 0.810 708 × 10^{-3}	acre feet (U.S. survey)	1 acre ft (U.S. survey)	= 1233.49	m^3
	= 1.307 95	yd^3	1 yd^3	= 0.764 555	m^3
	= 35.3147	ft^3	100 board ft	= 0.235 974	m^3
	= 423.776	board ft	1 ft^3	= 0.028 316 8	m^3
1 mm^3	= 61.0237 × 10^{-6}	in^3		= 28.3168	L (dm^3)
			1 in^3	= 16 387.1	mm^3
				= 16.3871	mL (cm^3)
			(FLUID) CAPACITY		
1 L	= 0.035 314 7	ft^3	1 gal (U.S. liquid)**	= 3.785 41	L
	= 0.264 172	gal (U.S.)	1 qt (U.S. liquid)	= 946.353	mL
	= 1.056 69	qt (U.S.)	1 pt (U.S. liquid)	= 473.177	mL
1 mL	= 0.061 023 7	in^3	1 fl oz (U.S.)	= 29.5735	mL
	0.033 814	fl oz (U.S.)			
		**	1 gal (U.K.) approx. 1.2 gal (U.S.)		
			SECOND MOMENT OF AREA		
1 mm^4	= 2.402 51 × 10^{-6}	in^4	1 in^4	= 416 231	mm^4
				= 0.416 231 × 10^{-6}	m^4
			PLANE ANGLE		
1 rad	= 57° 17′ 45″	(degree)	1° (degree)	= 0.017 453 3	rad
	= 57.2958°	(degree)		= 17.4533	mrad
	= 3437.75′	(minute)	1′ (minute)	= 290.888	µrad
	= 206 265″	(second)	1″ (second)	= 4.848 14	µrad
			VELOCITY, SPEED		
1 m/s	= 3.280 84	ft/s	1 ft/s	= 0.3048	m/s
	= 2.236 94	mile/h	1 mile/h	= 1.609 344	km/h
1 km/h	= 0.621 371	mile/h		= 0.447 04	m/s
			ACCELERATION		
1 m/s^2	= 3.280 84	ft/s^2	1 ft/s^2	= 0.3048	m/s^2
			VOLUME RATE OF FLOW		
1 m^3/s	= 35.3147	ft^3/s	1 ft^3/s	= 0.028 316 8	m^3/s
	= 22.8245	million gal/d	1 ft^3/min	= 0.471 947	L/s
	= 0.810 709 × 10^{-3}	acre ft/s	1 gal/min	= 0.063 090 2	L/s
1 L/s	= 2.118 88	ft^3/min	1 gal/h	= 1.051 50	mL/s
	= 15.8503	gal/min	1 million gal/d	= 43.8126	L/s
	= 951.022	gal/h	1 acre ft/s	= 1233.49	m^3/s
			TEMPERATURE INTERVAL		
1°C	= 1 K = 1.8°F		1°F	= 0.555 556	°C or K
				= 5/9°C = 5/9 K	

Metric to Customary			Customary to Metric		
EQUIVALENT TEMPERATURE VALUE ($t_{°C} = T_K - 273.15$)					
$t_{°C}$	= 5/9 ($t_{°F}$ − 32)		$t_{°F}$	= 9/5 $t_{°C}$ + 32	
MASS					
1 kg	= 2.204 62	lb (avoirdupois)	1 ton (short)***	= 0.907 185	metric ton
	= 35.2740	oz (avoirdupois)		= 907.185	kg
1 metric ton	= 1.102 31	ton (short, 2000 lb)	1 lb	= 0.453 592	kg
	= 2204.62	lb	1 oz	= 28.3495	g
1 g	= 0.035 274	oz	1 pennyweight	= 1.555 17	g
	= 0.643 015	pennyweight		= 1016.05	kg)
		***	(1 long ton (2240 lb)		
MASS PER UNIT LENGTH					
1 kg/m	= 0.671 969	lb/ft	1 lb/ft	= 1.488 16	kg/m
1 g/m	= 3.547 99	lb/mile	1 lb/mile	= 0.281 849	g/m
MASS PER UNIT AREA					
1 kg/m^2	= 0.204 816	lb/ft^2	1 lb/ft^2	= 4.882 43	kg/m^2
1 g/m^2	= 0.029 494	oz/yd^2	1 oz/yd^2	= 33.9057	g/m^2
	= $3.277\ 06 \times 10^{-3}$	oz/ft^2	1 oz/ft^2	= 305.152	g/m^2
DENSITY (MASS PER UNIT VOLUME)					
1 kg/m^3	= 0.062 428	lb/ft^3	1 lb/ft^3	= 16.0185	kg/m^3
	= 1.685 56	lb/yd^3	1 lb/yd^3	= 0.593 276	kg/m^3
1 t/m^3	= 0.842 778	ton/yd^3	1 ton/yd^3	= 1.186 55	t/m^3
MOMENT OF INERTIA					
1 $kg·m^2$	= 23.7304	$lb·ft^2$	1 $lb·ft^2$	= 0.042 140 1	$kg·m^2$
	= 3417.17	$lb·in^2$	1 $lb·in^2$	= 292.640	$kg·mm^2$
MASS PER UNIT TIME					
1 kg/s	= 2.204 62	lb/s	1 lb/s	= 0.453 592	kg/s
1 t/h	= 0.984 207	ton/h	1 ton/h	= 1.016 05	t/h
FORCE					
1 MN	= 112.404	tonf (ton-force)	1 tonf (ton-force)	= 8.896 44	kN
1 kN	= 0.112 404	tonf	1 kip (1000 lbf)	= 4.448 22	kN
	= 224.809	lbf (pound-force)	1 lbf (pound-force)	= 4.448 22	N
1 N	= 0.224 809	lbf			
MOMENT OF FORCE, TORQUE					
1 N·m	= 0.737 562	lbf·ft	1 lbf·ft	= 1.355 82	N·m
	= 8.850 75	lbf·in	1 lbf·in	= 0.112 985	N·m
1 kN·m	= 0.368 781	tonf·ft	1 tonf·ft	= 2.711 64	kN·m
	= 0.737 562	kip·ft	1 kip·ft	= 1.355 82	kN·m
FORCE PER UNIT LENGTH					
1 N/m	= 0.068 521 8	lbf/ft	1 lbf/ft	= 14.5939	N/m
1 kN/m	= 0.034 260 9	tonf/ft	1 lbf/in	= 175.127	N/m
			1 tonf/ft	= 29.1878	kN/m
PRESSURE, STRESS, MODULUS OF ELASTICITY (FORCE PER UNIT AREA) (1 Pa = 1 N/m^2)					
1 MPa	= 0.072 518 8	$tonf/in^2$	1 $tonf/in^2$	= 13.7895	MPa
	= 10.4427	$tonf/ft^2$	1 $tonf/ft^2$	= 95.7605	kPa
	= 145.038	lbf/in^2	1 kip/in^2	= 6.894 76	MPa
1 kPa	= 20.8854	lbf/ft^2	1 lbf/in^2	= 6.894 76	kPa
			1 lbf/ft^2	= 47.8803	Pa
WORK, ENERGY, HEAT (1 J = 1 N·m = 1 W·s)					
1 MJ	= 0.277 778	kWh	1 kWh	= 3.6	MJ
1 kJ	= 0.947 817	Btu	1 Btu (Int. Table)	= 1.055 06	kJ
1 J	= 0.737 562	ft·lbf	1 ft·lbf	= 1055.06	J
				= 1.355 82	J
POWER, HEAT FLOW RATE					
1 kW	= 1.341 02	hp (horsepower)	1 hp (550 ft·lbf/s)	= 0.745 700	kW
1 W	= 3.412 14	Btu/h	1 Btu/h	= 745.700	W
	= 0.737 562	ft·lbf/s	1 ft·lbf/s	= 0.293 071	W
				= 1.355 82	W
HEAT FLUX DENSITY					
1 W/m^2	= 0.316 998	$Btu/(ft^2·h)$	1 $Btu/(ft^2·h)$	= 3.154 59	W/m^2
COEFFICIENT OF HEAT TRANSFER					
1 $W/(m^2·K)$	= 0.176 110	$Btu/(ft^2·h·°F)$	1 $Btu/(ft^2·h·°F)$	= 5.678 26	$W/(m^2·K)$
THERMAL CONDUCTIVITY					
1 W/(m·K)	= 0.577 789	Btu/(ft·h·°F)	1 Btu/(ft·h·°F)	= 1.730 73	W/(m·K)
CALORIFIC VALUE (MASS AND VOLUME BASIS)					
1 kJ/kg (1 J/g)	= 0.429 923	Btu/lb	1 Btu/lb	= 2.326	kJ/kg (J/g)
1 kJ/m^3	= 0.026 839 2	Btu/ft^3	1 Btu/ft^3	= 37.2589	kJ/m^3
THERMAL CAPACITY (MASS AND VOLUME BASIS)					
1 kJ/(kg·K)	= 0.238 846	Btu/(lb·°F)	1 Btu/(lb·°F)	= 4.1868	kJ/(kg·K)
1 $kJ/(m^3·K)$	= 0.014 910 7	$Btu/(ft^3·°F)$	1 $Btu/(ft^3·°F)$	= 67.0661	$kJ/(m^3·K)$
MOISTURE (VAPOR) MOVEMENT					
1 $\mu g/(Pa·s·m^2)$	= 17.4057	perm (23°C)	1 perm (23°C)	= 57.4525	$ng/(Pa·s·m^2)$
1 ng/(Pa·s·m)	= 0.685 26	perm-in (23°C)	1 perm/in. (23°C)	= 1.459 29	ng/(Pa·s·m)
ILLUMINANCE					

Metric to Customary			Customary to Metric		
1 lx (lux)	= 0.092 903	lm/ft^2(footcandle)	1 lm/ft^2(footcandle)	= 10.7639	lx (lux)
		LUMINANCE			
1 cd/m^2	= 0.092 903	cd/ft^2	1 cd/ft^2	= 10.7639	cd/m^2
	= 0.291 864	footlambert	1 footlambert	= 3.426 26	cd/m^2
1 kcd/m^2	= 0.314 159	lambert	1 lambert	= 3.183 01	kcd/m^2

X2. SUPERSEDED METRIC UNITS NOT RECOMMENDED FOR USE WITH SI

X2.1 It is strongly recommended that the traditional and "cgs" metric (non-SI) units listed below be *avoided* in building design or construction applications. Any data showing these units should be converted to the appropriate SI units that supersede them.

Unit Name	Symbol	Value in SI Units		
dyne	dyn	10^{-5}	N	(or 10 μN)
bar	bar	10^{5}	Pa	(or 100 kPa)
erg	erg	10^{-7}	J	(or 100 nJ)
poise	P	10^{-1}	Pa·s	(or 100 mPa·s)
stokes	St	10^{-4}	m^2/s	(or 100 mm^2/s)
gauss	Gs,(G)	10^{-4}	T	(or 100 μT)
maxwell	Mx	10^{-8}	Wb	(or 10 nWb)
stilb	sb	10^{4}	cd/m^2	(or 10 kcd/m^2)
phot	ph	10^{4}	lx	(or 10 klx)
kilogram-force	kgf	9.806 65		N
calorie (int.)	cal	4.1868		J
kilocalorie (int.)	kcal	4.1868		kJ
langley	ly	4.184		kJ/m^3
torr	torr	133.322		Pa
oersted	Oe	79.5775		A/m

X3. SI UNITS AND RELATIONSHIPS CHART

X3.1 The SI Units and Relationships Chart (Fig. X3.1) emphasizes four categories of SI units, their unit symbols, and their relationships:

X3.1.1 Base units,
X3.1.2 Supplementary units,
X3.1.3 Derived units expressed in terms of base units, and
X3.1.4 Derived units with special names.

X3.2 Arrows indicate the derivation of all derived units with special names:

X3.2.1 Solid lines represent a relationship in which the derived unit is a product of the constituent units (J = N·m; Wb = V·s).

X3.2.2 Broken lines represent a relationship in which the derived unit is a quotient of the constituent unit (Hz = 1/s; S = 1/Ω).

X3.2.3 Solid and broken lines indicate a relationship involving both a product and a quotient (Pa = N/m^2; W = J/s; Ω = V/A).

X3.2.4 The degree Celsius (°C) is shown as a derived unit, related directly to the kelvin (K) with the temperature interval 1°C = 1 K, and the temperature value $t_{°C} = T_K - 273.15$.

X3.3 There are a total of 27 SI units with names and symbols on the chart. Of these:

X3.3.1 Thirteen, almost one half the total, are already in general use: s, A, cd, Hz, W, V, C, F, H, Ω, lm, rad, and sr.

X3.3.2 One, the siemens (S), was previously referred to as "mho," so that it is a new name only.

X3.3.3 Three have almost no application in design and construction:
mole (mol) = base unit for amount of substance
becquerel (Bq) = derived unit for activity (of a radionuclide)
gray (Gy) = derived unit for absorbed dose

X3.4 Thus, a maximum of ten new units in SI will need to be learned:

m, kg, K, °C, N, Pa, J, Wb, T, lx

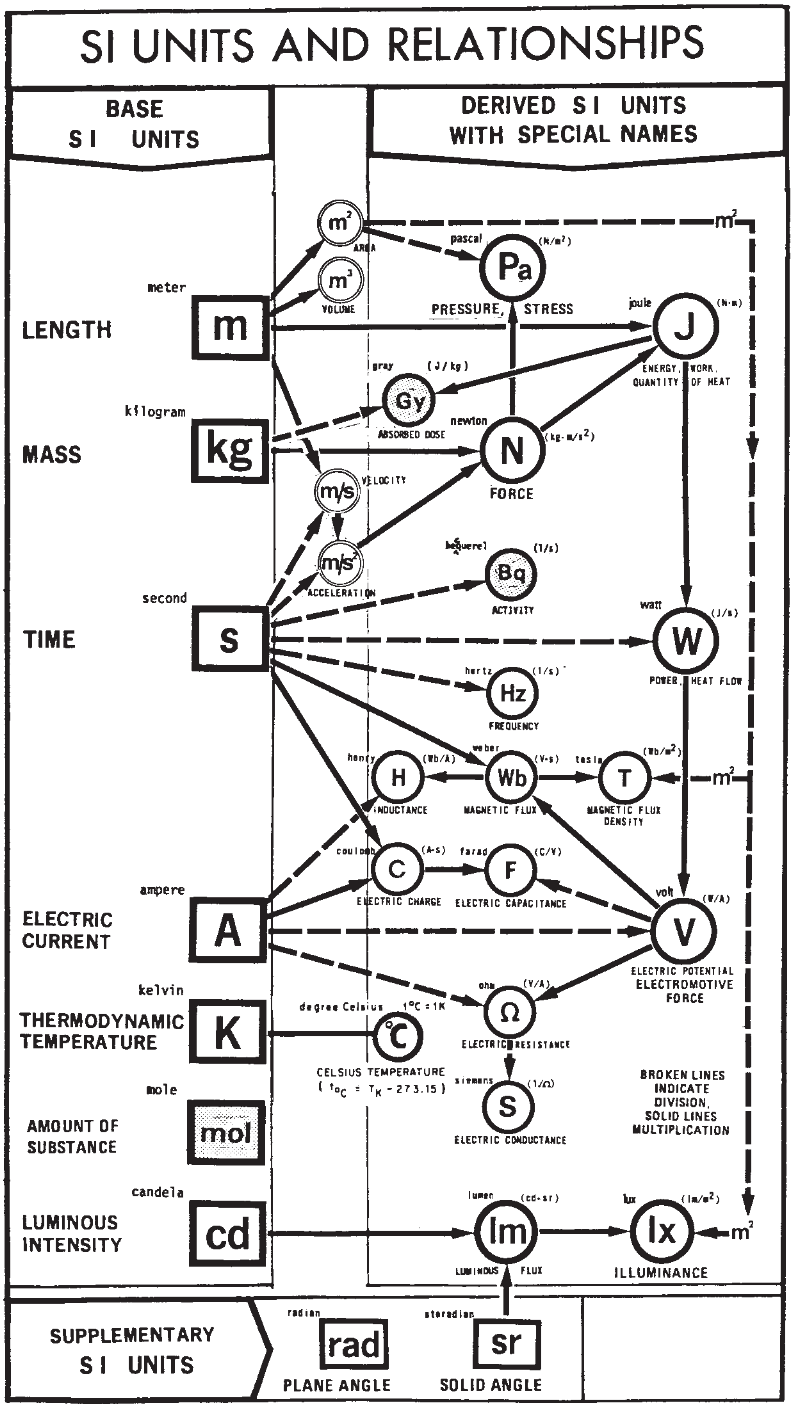

FIG. X3.1 SI Units and Relationships

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(**3**) U.S. Department of Commerce/National Bureau of Standards NBS Special Publication 330, *The International System of Units (SI)* (1978 Revised Edition)
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(**7**) Series of International Standards ISO/31, Quantities and Units of SI: ISO 31/0-1974 General Introduction to ISO 31-*General Principles Concerning Quantities, Units, and Symbols* ISO 3/I-1978 *Quantities and Units of Space and Time* ISO 31/II-1978 *Quantities and Units of Periodic and Related Phenomena* ISO 31/III-1978 *Quantities and Units of Mechanics* ISO 31/IV-1978 *Quantities and Units of Heat* ISO 31/V-1979 *Quantities and Units of Electricity and Magnetism* ISO 31/VI-1973 *Quantities and Units of Light and Related Electromagnetic Phenomena*
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