Metric Criteria
Transportation Projects

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Metric Criteria: Transportation Projects

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Introduction:

The Mississippi Department of Transportation (MDOT) hereby adopts the international system of measurement known as the metric system for all transportation work in the State of Mississippi. This system is named *Systéme International d'Unites* (System International) and is abbreviated SI. Throughout this document the use of the terms *metric* and *metric system* shall mean SI.

The MDOT hereby adopts the AASHTO's *A Policy on Geometric Design of Highways and Streets, 1994*. This publication is the official design criteria of the *American Association of State Highway and Transportation Officials* (AASHTO).

All MDOT construction projects awarded to contract after September 30, 2000, is intended to be metric only. During the period from now through September 30, 2000, the MDOT may award some projects in the current Imperial (English) system and some projects in the SI (metric) system.

The *Metric Conversion Act of 1975*, as amended by the *Omnibus Trade and Competitiveness Act of 1988*, established the metric system as the preferred system of measurement in the United States. Presidential Executive Order 12770, July 25, 1991, mandates each Federal agency and Federal program convert to the Metric System. The Federal Highway Administration (FHWA) requires all Federal highway construction projects to be Metric only by September 30, 2000. (NOTE: The FHWA originally set September 30, 1996, as the required implementation date; however, the *National Highway System (NHS)* act of 1995 postponed this date to the year 2000.) This document is the MDOT criteria to be used to meet this requirement. The MDOT will use metric only for all projects (Federal and State). Because surveyors, designers, inspectors, etc. can't effectively and accurately use a dual system the MDOT has decided that no Imperial (English) units will be used (except for dual units shown on certain public documents as described later in these criteria).

Included in this document are the approved MDOT criteria for use in the planning, design, and construction of all transportation facilities in the State of Mississippi. The document is divided into four (4) sections:

I. MDOT Metric Criteria,
II. Metric Conversion Techniques,
III. Reference Guides,
IV. MDOT Implementation Schedule.

This Criteria Document is not intended to be the complete standards and specifications for all transportation construction. This document describes adopted units and criteria. The MDOT uses other publications that establish *Design Standards, Standard Drawings, Construction Specifications, Standard Operating Procedures, Materials Testing and Sample Collection* values.

Section I. of this document includes criteria for roadway traverses and design.

Criteria are included for:

1. Precision and Units,
2. Roadway stationing,
3. Selecting and describing horizontal roadway curves,
4. Cross sections,
5. Drafting scales,
6. Elevations and slopes,
7. Environmental Documents,
8. Right-of-Way plats and deeds,
9. Materials and testing,
10. Road, Street, and Construction Zone signs,
11. Construction pay item units,
12. Structures.

The criteria will be used for all MDOT engineering, design, traverses, plans, testing, reporting, mapping, etc. It is considered absolutely essential that all offices use the same criteria for transportation purposes in the State of Mississippi.

There are two types of metric conversion: *Hard* and *Soft*. Hard conversion is the changing of criteria to a new standard based on logical metric values.

> *Hard* metric conversion can be illustrated by design lane widths. Before 1994, roads have been designed with 12 feet lane widths. The new metric criteria is 3.6 meters (11.81 feet.)
>
> *Soft* metric values are the use of conversion factors to change an existing Imperial (English) value to its metric equivalent. For example: 500 feet = 152.400 meters.

The MDOT will use *Hard* metric conversion where criteria have been established by AASHTO or FHWA. *Soft* conversion will be used for all other values.

The MDOT has adopted the symbol/logo shown below to denote metric documents.

All SI (metric) specifications, plans, project documents, reports, and any other SI material produced or printed by the MDOT shall include the logo prominently displayed. Metric construction plans will contain the logo near the title block (or near the right margin for plan/profile sheets) of all plan sheets. The MDOT metric logo is not to be used on any document that is not metric. The logo is available in several graphic computer formats and is distributed free of charge. Contact the MDOT Metric Coordinator for available formats and copies of the logo.

SECTION I: MDOT Metric Criteria:

1. Precision and Units:

Conversion of all numbers to the metric system must retain at least the accuracy and precision currently in use. Usually, this means showing metric values to one decimal place more than has been used for Imperial (English) units.

Example:

> The meter is the unit of length for the metric system; therefore, the meter must be measured to the third (3 rd) decimal place (0.001 m) to retain the same accuracy as one hundredth of a foot (0.01 ft.)
>
> When a measurement has in the past been shown to the nearest 0.01 feet the new metric value is to be shown to 0.001 meters.
>
> NOTE: While 0.001 m is more accurate than 0.01 ft. the use of 0.01 m would be less accurate than 0.01 ft and therefore precision would be lost. (Actually 0.01 ft = 0.003 048 m).

Measurement precision criteria are as follows:

Table I-1: Precision (distances)

Measurement Item (for all roadways)	Criteria Meters
Horizontal distance, except cross sections	0.001
Elevations: Benchmarks	0.001
Elevations: Centerline, Pavements	0.001
Elevations: Centerline, Subgrades	0.005
Cross sections: Distances	0.1
Cross sections: Elevations on ground: (1)	0.05
Cross sections: Elevations on pavement(1)	0.005

(1) These values are not as precise as the Imperial (English) values in use in the past. The compromise is necessary due to available equipment from suppliers.

Standard measuring units for metric use in the MDOT are as follows:

Table I-2: Units

Item:	Unit:	Sym.
Distance (2)	meter	m
Bridge Plans:		
Plan & Elev(2)	meter	m
All other dim(2)	millimeter	mm
Testing (3)	centimeter	cm
Angles	degree minute second	° ' "
AREAS:		
Construction (4)	square meter	m^2
ROW deeds	hectare	ha
Large Areas	square kilometer	km^2
Volume,const.	cubic meter	m^3
Volume,liquids	liter	L
Mass (5)	kilogram	kg
Mass (small)	gram	g
Mass (large)	metric ton (1000 kg)	t
Force	newton	N
Temperature	Celsius	°C
Pressure	pascal	Pa
Time:	second	s
	minute	min.
	hour	h
	day	d
Discharge	cubic meter per second	m^3/s
Velocity	meters per second	m/s
Depths	millimeter	mm
Intensity	millimeters per hour	mm/h
Density	kilograms per cubic meter	kg/m^3
Gravity Const.	meters per second squared	m/s^2
Speed	kilometers per hour	km/h

(2) All distance measurements (and pay quantities that use distance) will use meters or millimeters without reference to the word "linear." Previous Imperial (English) units called for "linear feet" but SI will only use the metric value, example: 20 linear feet of beam would be expressed as 6.096 m.

(3) Centimeters are not accepted practice in the MDOT for most measurements. However, some AASHTO and ASTM test procedures call for centimeter values and will be accepted practice only in those applicable test methods.

(4) When using symbols indicating area and volume the correct notation is to use the exponent as shown in the table; however, sometimes these become illegible. In special applications it is allowable to use the abbreviations *sq.* or *cu.* to indicate square and cubic measures. An example is construction plans which are routinely reduced to 1/2 scale for printing and distribution. The correct way to use this exception is: *sq. m* or *cu. m.*

(5) Weight is used in the Imperial (English) system to represent a quantity of material. The SI system uses mass. Grams will be used for ounces, kilograms for pounds, and metric tons for tons.

Table I-3: Prefixes

Prefix	Symbol	Order of Magnitude	Expression
kilo	k	10^3	1000 (one thousand)
mega	M	10^6	1 000 000 (one million)
milli	m	10^{-3}	0.001 (one thousandth)
micro	μ	10^{-6}	0.000 001 (one millionth)
nano	n	10^{-9}	0.000 000 001 (one billionth)

2. Stationing:

Roadway surveys and plans use the metric kilometer stationing system. The numbers before the "plus mark" (+) are in kilometers from the starting point of the highway within a county. The numbers following the "plus mark" (+) are in meters and decimals of a meter. Decimals of a meter will always be expressed to three decimal places anytime a station is written.

Examples:

Station 2 + 486.123 = 2 kilometers (km) from the starting point plus 486.123 meters

Station 3 + 000.000 is exactly 3 km from the starting point. Note three zeros are placed following the decimal point. Other samples:

0 + 110.220
3 + 002.100
10 + 200.000

The kilometer values are to be the elapsed distance from the county line, (or from the beginning of a route if the route starts within the county) plus one kilometer. The beginning station number at the county line will be one kilometer (1 + 000.000) instead of zero. This will prevent negative station numbers when a project must begin before the county line such as a bridge. All routes are to be stationed from the south to the north for odd numbered highways and from the west to the east for even numbered highways. Routes that are diagonal in nature are to be stationed based on whether the route number is even or odd.

Example:

MS 19 is an odd numbered route that goes from the Alabama State Line in Lauderdale County northwest to Holmes County. The stationing should start with one kilometer at the Alabama State Line in Lauderdale County and proceed northwest to the Newton County Line. The stations should start over at the Newton County Line with one kilometer and proceed northwest to the Neshoba County Line. Each succeeding county will then have new kilometer stations starting at one kilometer at the previous county line.

When a new project is started on a route the Project Office or District Office is responsible for determining the correct station of the *Beginning of Project* (B.O.P.) Existing plans should be used to calculate the correct elapsed distance in kilometers and meters from the beginning point in the county to use as the Station for the B.O.P.

Example:

PROBLEM:

Determine the B.O.P. Metric Station for a new project on an existing road.

GIVEN:

Previous project for an even numbered route has Sta. 1102 + 22.34 in feet, at the West County Line. The project has an E.O.P. of Sta. 1419+24.64 ft. No equations exist on the project. The new metric project will begin at the old Sta. 1317+00.00 ft.

SOLUTION:

B.O.P. of new project is calculated as follows:
Sta. 1317 + 00.00 ft. - 1102 + 22.34 ft. = 21,477.66 feet from the county line.

Metric distance is
21,477.66 X 1200 / 3937 = 6546.403 86 m

Therefore, the Metric B.O.P. Station number is 6.546 403 86 kilometers plus 1 kilometer added for county line default:
Sta. 7 + 546.404

Equations will eventually be required to correct minor differences and alignment changes; however, no new metric project should have an equation. If a new metric project is replacing stationing on a road where an equation exists in current feet stations then kilometer stations on the new project are to be calculated without an equation.

3. Circular Horizontal Curves:

Curves will be selected based on the Radius of the Curve in meters. The definition of curves using a degree designation is no longer valid. All curves will have the following information shown in the notes and on the plans:

Delta Angle in Degrees Minutes and Seconds.

Radius in meters.

Length in meters.

Tangent distance in meters.

Metric stations of the P.C., P.I., & P.T.

Long Chord length in meters and the bearing of the Long Chord in Degrees, Minutes, and Seconds.

All new routes (or where horizontal alignment on existing routes are changed) are to be designed using the exact metric radius without regard to its equivalent degree of curve.

Metric roadway construction plans for projects on existing roadway alignment will be soft converted. The exact metric radius will be converted from the existing Imperial (English) plans without regard to Table I-4. When designing a route parallel to an existing route (which was designed using Imperial (English) units) the new roadway will be designed using a curve radius calculated to be parallel with the existing roadway. An exception to this rule will be when the median is not held to constant width but varies. The new parallel roadway should then use the metric values shown in Table I-4. Table I-4 is included for selecting appropriate curves indicating the metric curve radius to replace the curves that would have been chosen based on the old Imperial (English) units. The radius in meters **is not** the exact radius of the old degree of curve value converted from feet. The metric radii shown are rounded.

Table I-4: Horizontal Highway Curves

Metric Design Radius Meters	Approved Range (Meters)	Equivalent Degree Curve* (English)
20 000		0°05'
15 000	5000	0°07'
10 000	-------------	0°10'
7000	3000	0°15'
5000	2000	0°21'
4000	1000	0°26'
3000	-------------	0°35'
2500		0°42'
2000	500	0°52'
1500	-------------	1°10'
1400		1°15'
1300		1°21'
1200		1°27'
1100	100	1°35'
1000		1°45'
900		1°56'
800	-------------	2°11'
750		2°20'
700		2°30'
650	50	2°41'
600		2°55'
550		3°11'
500	-------------	3°30'
475		3°41'
450	25	3°53'
425		4°07'
400		4°22'
375		4°39'
350		4°59'
325		5°22'
300	-------------	5°49'
290		6°01'
280		6°14'
270		6°28'
260		6°43'
250		6°59'
240		7°17'
230		7°36'
220		7°56'
210	10	8°19'
200		8°44'
190		9°11'
180		9°42'
170		10°16'
160		10°56'
150	-------------	11°39'
145		12°03'
140		12°28'
135		12°56'
130		13°26'
125		13°58'
120		14°33'
115		15°11'
110		15°53'
105		16°38'
100	5	17°28'
95		18°23'
90		19°24'
85		20°33'
80		21°50'
75		23°18'
70		24°57'
65		26°52'
60		29°06'
55		31°45'
50		34°56'

* Degree-of-Curve in the English system is included for guidance. Values shown are the equivalent Degree-of-Curve for the metric radius rounded to the nearest minute.

4. Cross Sections:

Cross sections will be taken at 25 meter intervals.

Also, cross sections will continue to be taken at other locations where required by the terrain. Precision of the data collection for distances and elevations of cross sections is shown above in the paragraph titled *Precision and Units.*

5. Drafting Scales:

Table I-5: Scales

Media	Previous English Scale	MDOT Metric Scale
Plans: Rural	1" = 100'	**1 : 1000**
Plans:Ru.& Ur	1" = 40'	**1 : 500**
Plans: Urban	1" = 20'	**1 : 250**
Profile: Rural	1" = 10'	**1 : 100**
Profile: Urban	1" = 5'	**1 : 50**
X-Sect. Rural	1" = 10'	**1 : 100**
X-Sect. Urban	1" = 5'	**1 : 50**
Other	1" = 1'	**1 : 10**
	1" = 2'	**1 : 20**
	1" = 50'	**1 : 500**
	1" = 400'	**1 : 5000**
Photogrammetry	1" = 200'	**1 : 2000**
	1" = 500'	**1 : 5000**
	1" = 1000'	**1 : 10 000**
	1" = 2000'	**1 : 20 000**
Mapping: City Maps	1" = 528' & 1" = 666'	**1 : 5000**
City Maps	1" = 1056'	**1 : 10 000**
City Maps	1" = 1320'	**1 : 25 000**
County Maps	1" = 1 mile	**1 : 63 360**
County Maps	1" = 2 miles	**1 : 126 720**
County Maps	1" = 3 miles	**1 : 190 080**

6. Elevations:

Precision (Benchmarks):

All elevations will be measured and displayed to the nearest 0.001 meter.

Roadway Centerlines & Grades:

All roadway and street subgrade elevations will be measured and displayed to the nearest 0.005 meter.

All roadway and street final paving elevations will be measured and displayed to the nearest 0.001 meter.

Elevations, Cross Sections:

Cross section elevations will be measured on ground to the nearest 0.05 meter and on pavement to the nearest 0.005 meter.

Slopes:

All side slopes on roadway cross-sections will be expressed as dimensionless units. The slope will be expressed as a ratio with the vertical distance expressed first and the horizontal distance second. This is a change from the previous Imperial (English) system. Previously a roadway foreslope that drops one foot for each four feet horizontally was expressed as 4:1. On all metric plans and cross-sections this same slope will be expressed as 1:4.

7. Environmental Documents:

Environmental Documents (Categorical Exclusions, Environmental Assessments, Environmental Impact Studies, Noise Studies, etc.) have dual metric and Imperial (English) units since April 1, 1994. These documents will continue to include dual units.

8. Right-of-Way (ROW) Plats & Deeds:

The Federal Highway Administration (FHWA) has approved dual units on ROW plats and deeds.

The MDOT will use both metric and Imperial (English) units on all ROW plans, plats, and deeds. Property lines will be shown in standard "metes & bounds" using dual metric and Imperial (English) units. Property lines will show standard quadrant bearings expressed in degrees, minutes, and seconds with distances shown in meters followed by feet in parentheses. Metric distances will be to the nearest 0.001 meter. All metric distances on plats and deeds are to spell out the word "meters" instead of using the abbreviation "m".

Example:

N 22°15'30" E 238.145 meters (781.31 ft.)

Area will be shown in either of two ways: square meters or hectares.

For large areas use hectares followed by the area in acres within parentheses.

Example:

Lot Area: 2.235 hectares (5.52 acres)

Area expressed in square meters may be preferable for very small areas. When area is expressed in square meters then the area in square feet will follow in parentheses.

Example:

Area: 155 square meters (1668.40 sq.ft.)

One (1) hectare is defined as 10 000 square meters. Also, one hectare is equal to 107,638.674 square feet (US survey foot definition). To convert from acres to hectares multiply the acres by:

0.404 687

9. Materials and Testing:

Roadway Sub-surface Investigations, Type C:

Determine locations and depth of auger borings, under the following guidelines:

a. Prior experience for locality.

b. The boring depths shall be 1.5 meters below the proposed finished grade for cut sections and grade points. The boring depths shall be 1.5 meters below the existing ground surface for embankment sections.

c. Space borings 150 meters maximum, less in critical stratification spacing.

10. Road, Street, and Construction Zone Signs:

All road and street signs will continue to display Imperial (English) messages for speeds and distance. The FHWA has decided to postpone conversion of road signs until sometime in the future. No metric values will be shown on any Mississippi road and street signs until the nation decides to convert.

11. Construction Pay Item Units:

The following table shows the adopted MDOT metric pay item units for all road and street construction. The table shows the SI (metric) values on the left and includes the old Imperial (English) units on the right for reference. For all construction pay items that used the unit shown in the Imperial column substitute the metric pay item unit.

Table I-6: Construction Pay Units

SI (metric) Unit	Imperial Unit
station *	station
bale	bale
cubic meter	cubic foot
cubic meter	cubic yard
each	each
gram	ounce
hectare	acre
hour	hour
kilogram	pound
kilometer	mile
liter	gallon
lump sum	lump sum
meter	yard
meter	foot
metric ton	ton
millimeter	inch
square meter	square foot
square meter	square yard

* metric station = 1 kilometer, which replaces the existing station in Imperial (English) units of station = 100 feet.

12. Structures:

A bridge is defined as any structure, including supports, erected over a depression or an obstruction. This includes water, highways, or railways, and having a tract or passageway for carrying traffic or other moving loads. A bridge is also defined as such structure having a length measured along the center line of the roadway of more than 6.1 m between undercopings of abutments, or extreme ends of openings for multiple boxes.

When existing structures must either be field measured or converted from plans all dimensions will be measured in millimeters. This includes box bridges and culverts.

All construction shop drawings, or working drawings, for structures shall be submitted in metric units only. All shop inspection will be performed using metric units.

All portland cement concrete used in roadway and structure construction will conform to the following values:

Table I-7: Accepted Concrete Strengths:

Metric Criteria (MPa)	Actual Concrete Strength (psi)	Replaces Concrete Strength (psi)
15	2175	2000
20	2901	2500
25	3626	3000
30	4351	4000
35	5076	5000
40	5801	6000

SECTION II: Imperial (English) to Metric Conversion Techniques:

1. Feet to Meters Conversion:

There are two (2) definitions of the foot in the metric system. The International Foot is defined as exactly 0.3048 meters. The United States has always used the U.S. Survey Foot which is defined as 1200 / 3937 meters. This produces an inexact conversion factor. Because the US Survey foot conversion factor is not an exact value accurate conversion must use both numbers in the conversion process.

Example: To convert 10,000 feet to meters the results of using the two different conversion values are:

International Factor:
10,000' * 0.3048 = 3048.000 meters.

US Survey Foot:
10,000' * 1200 / 3937 = 3048.006 096.... meters.

Obviously, conversion using the International foot method is adequate for small distances. However, the error can accumulate if the values being converted represent parts of longer distances. Also, computation of short distances that are used in area calculations will make the results inaccurate if the correct conversion value is not used.

The MDOT adopts the following guidelines for conversion of feet to meters:

US Survey Foot Conversion Method:

The US Survey Foot method **must** be used for the following values:

1. Benchmark elevations;
2. Roadway centerlines;
3. Land Area;
4. Traverse (survey) lines;
5. Logmile to log-kilometers;
6. Digital coordinates;
7. All other distances where values will be accumulated to totals larger than 1500 meters.

Conversion of all above distances in feet **must** use the following conversion method:

Feet to Meters: Multiply by 1200 then divide by 3937.

Meters to Feet: Multiply by 3937 then divide by 1200.

Note: The factor should be calculated each time it is needed. Otherwise accuracy will be lost. However, if a memory calculator is used (i.e. Hewlett Packard HP-41C, etc.) then you could enter 1200, divide by 3937, store in a memory register, then recall the value each time it is needed.

Standard Conversion Factor:

The International Foot conversion factor may be used for short distances (less than 1500 meters) and items not a part of those identified above.

Example: To convert feet to meters:

Multiply feet by 0.3048 to obtain meters.

Land Area Calculations:

Conversion from acres to hectares will use the US Survey foot conversion. The following factor is to be used for acres to hectares:

Multiply acres by 0.404 687 to get hectares

2. Metric Conversion Factors:

The standard for the SI system in the United States is the American Society for Testing and Materials (ASTM) publication E-380 titled *Standard Practice for Use of the International System of Units, SI , The Modernized Metric System.* This standard has been approved for use by agencies of the Federal Government. The MDOT hereby adopts ASTM E-380 as the official standard for SI practice for Transportation in the State of Mississippi. ASTM E-380 is copyrighted by ASTM. ASTM E-380 may be purchased from:

ASTM
1916 Race Street
Philadelphia, PA 19103

Table II-1: ASTM E-380-93 Conversion Factors (abridged list):

To Convert From	To	Multiply by:
acre foot	cubic meter (m^3)	1233.49
acre	square meter (m^2)	4046.87
acre	hectare	0.404 687
ampere hour	coulomb (C)	3600
atmosphere, standard	pascal (Pa)	101 325.0
barrel (petroleum, 42 gal)	cubic meter (m^3)	0.158 987 3
board foot	cubic meter (m^3)	0.002 359 737
chain (66 ft)	meter (m)	20.116 84
degree Fahrenheit	degree Celsius (°C)	$T_C = (T_F - 32) / 1.8$
fluid ounce (U.S.)	cubic meter (m^3)	0.000 029 573 53
fluid ounce (U.S.)	milliliter (mL)	29.573 53
foot (International)	meter (m)	0.3048
foot (U.S. Survey foot)	meter (m)	1200 / 3937
foot of water (39.2 °F)	pascal (Pa)	2988.98
square foot	square meter (m^2)	0.092 903 04
ft^2/s (square feet per second)	square meter per second (m^2/s)	0.092 903 04
ft^3/min (cubic feet per minute)	cubic meter per second (m^3/s)	0.000 471 947 4
ft^3/s (cubic feet per second)	cubic meter per second (m^3/s)	0.028 316 85
ft/s (feet per second)	meter per second (m/s)	0.3048
gallon (U.S. dry)	cubic meter (m^3)	0.004 404 84
gallon (U.S. liquid)	cubic meter (m^3)	0.003 785 412
inch	meter (m)	0.0254
inch of mercury (32°F)	pascal (Pa)	3386.38
kip (1000 lbf)	newton (N)	4448.22
kip / in^2 (ksi)	pascal (Pa)	6 894 757.0
mile (U.S. statute)	kilometer (km)	1.609 347
mi^2	square kilometer (km^2)	2.589 988
mph (miles per hour)	kilometer per hour (km/h)	1.609 347
ounce (weight)	gram	28.349 523
pound (lb avoirdupois)	kilogram (kg)	0.453 592 37
lb • ft^2 (moment of inertia)	kilogram square meter (kg • m^2)	0.042 140 11
lb/ft^2 (pounds per square foot)	kilogram per square meter (kg/m^2)	4.882 428
ton (short, 2000 lb)	kilogram (kg)	907.1847
yd^2 (square yards)	square meter (m^2)	0.836 127 4
yd^3 (cubic yards)	cubic meter (m^3)	0.764 554 9

3. Rules for Writing Metric Symbols & Names:

Meter can be spelled either *meter* or *metre.* In the United States the spelling *meter* has been adopted. Most European countries use *metre.* Correct grammatical usage of metric terms is important. For example: the *Webster' Collegiate Dictionary*, 10th edition defines two words as follows:

> *Metricized* - verb or adjective, Examples: Verb - documents which are metricized. Adj. - a metricized document
>
> *Metrication* - noun or adjective (never a verb), Examples: Noun - the perceived urgency of metrication (object of the preposition). Adj. - metrication effort of the Metric Clearinghouse.
>
> (NOTE: The terms *metrification, metricated,* and *metricating* are not proper words.)

Care must be taken to use unit symbols properly, and international agreement provides uniform rules. Handling of unit names varies because of language differences, but use of the rules included here will improve communications in Mississippi and the nation.

- Print unit symbols in upright type and in lower case except for liter (L) or unless the unit name is derived from a proper name. (Examples: m for meter, kg for kilogram, Pa for pascal, etc.)
- Print unit names in lower case, even those derived from a proper name.
- Print decimal prefixes in lower case for magnitudes 10^3 and lower. Examples: k for kilo (10^3), m for milli (10^{-3}), μ for micro (10^{-6}), n for nano (10^{-9}), and print the prefixes in upper case for magnitudes 10^6 and higher M for Mega (10^6) and G for Giga (10^9).
- Leave a space between a numeral and a symbol.

    Examples: write 45 kg for 45 kilograms, not 45kg, and 200 m for 200 meters, not 200m.

    Exception: No space is left between the numerical value and the symbols for degree, minute, and second of plane angles and degree Celsius. Write N 22°15' W not N 22 ° 15 ' W and 37°C not 37 °C.

    When a quantity expressed as a number and a unit symbol is used as an adjective, it is preferable to use a hyphen instead of a space. Examples: a three-meter pole is 3 m long, and use 35-mm film which is 35 mm wide.

- Use a degree mark with Celsius temperature. Do not use a space between the number and the symbol. Example: 37°C not 37 °C. (If kelvin is used then do not use a degree mark. Write 312 K, not 312°K).
- Do not leave a space between a unit symbol and its decimal prefix. Write kg not k g.
- Do not use the plural of unit symbols. Write 45 kg, not 45 kgs. But, do use the plural of written unit names, e.g. write 45 kilograms not 45 kilogram.
- For technical writing, use symbols in conjunction with numerals (the area is 10 m^2); write out unit names if numerals are not used. Example: "reseal is measured in square meters." Numerals may be combined with written unit names in non technical writing (i.e. 10 meters). Never use abbreviations for metric values. Example: Use the word "ampere" or the symbol "A" and never use "amp".
- Indicate the product of two or more units in symbolic form by using a dot positioned above the line. Example: kg • m • s^{-2}.
- Do not mix names and symbols. Write N • m or newton meter, not N • meter.
- Do not use a period after a symbol (write "12 g" and not "12 g.") except when it occurs at the end of a sentence.
- Do not use prefixes that express the powers of 10 such as "deci" for one tenth (i.e. decimeter), and "centi" for one hundredth (i.e. centimeter). Use only the thousand multipliers shown in Table I-3, Prefixes above (kilo and milli).
- No space or hyphen is used between the prefix and unit name. There are three cases where the final vowel in the prefix is commonly omitted: *megohm, kilohm*, and *hectare*. In all other cases where the unit name begins with a vowel both vowels are retained and both are pronounced.

4. Numbers:

The approved decimal marker is a dot (period) on the line. When writing numbers less than one, a zero should always be written before the decimal marker.

The approved marker for separating the digits of numbers into groups of three is the space. No separator is to be used if there are only four (4) digits either to the left or right of the decimal point. However, when a column of numbers occur where the digits should align vertically the space may be used with four digit number groups. When there are five or more digits, left or right of the decimal, then a space must be used. The only exceptions to this is the use of numbers in financial statements and the use of numbers in construction plans and specifications where metric units are not involved, such as population. For all values where metric units are involved the comma is not approved for use with any engineering plans, specifications, reports, etc. within the Transportation discipline in Mississippi. Commas can be used with metric numbers only when used in financial reports and other specialized data items where other items are involved using comma separators.

Examples:

123 456.215 67 m
2345.789 kg
2 345 678.11 Pa
0.123 m

5. Pronunciation:

Table II-2

Prefix	Pronunciation (USA)
exa	**ex'** a (as in about)
peta	**pet'** a (e as in pet, a as in about)
tera	as in terra firma
giga	**jig'** a (j as in jig, a as in about)
mega	as in megaphone
kilo	**kill'** oh
hecto	**heck'** toe
deka	**deck'** a (a as in about)
milli	as in military
micro	as in microphone
nano	**nan'** oh (an as in ant)
pico	**peek'** oh
femto	**fem'** toe (fem as in feminine)
atto	as in anatomy

Units	Pronunciation
candela	can **dell'** a
joule	rhymes with tool
kilometer	**kill'** oh meter
pascal	rhymes with rascal
siemens	same as seamen's

6. Metric (SI) Classes of Units:

SI units are divided into three classes:

base units
supplementary units
derived units

The metric system is based on seven well-defined units which by convention are regarded as dimensionally independent (see ASTM E-380 Table II-3 below.)

Table II-3 Base SI Units ASTM E-380

Quantity	Unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
temperature *	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

* MDOT will use Celsius instead of kelvin.

Table II-4 Supplementary SI Units ASTM E-380

Quantity	Unit	Symbol
plane angle	radian	rad
solid angle	steradian	sr

7. Rule for Dual Units:

In those documents where dual units are allowed, the metric value will <u>always</u> be first followed by the Imperial (English) value in parentheses. Example:

275 kilometers (170.88 miles)

Table II-5 Derived SI Units with Special Names ASTM E-380

Quantity	Unit	Symbol	Formula
frequency (of a periodic phenomenon)	hertz	Hz	1/s
force	newton	N	kg • m/s²
pressure, stress	pascal	Pa	N/m²
energy, work, quantity of heat	joule	J	N • m
power, radiant flux	watt	W	J/s
quantity of electricity, electric charge	coulomb	C	A ● s
electric potential,	volt	V	W/A
electric capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
electric conductance	siemens	S	A/V
magnetic flux	weber	Wb	V • s
magnetic flux density	tesla	T	Wb/m²
inductance	henry	H	Wb/A
Celsius temperature	degree Celsius	°C	$T_C = T_K - 273.15$
luminous flux	lumen	lm	cd • sr
illuminance	lux	lx	lm/m²
activity (of a radionuclide)	becquerel	Bq	1/s
absorbed dose	gray	Gy	J/kg
dose equivalent	sievert	Sv	J/kg

Table II-6 Other MDOT Approved Units in use with SI

Quantity	Unit	Symbol
time	second	s
	minute	min
	hour	h
	day	d
speed	kilometer per hour	km/h
plane angle	degree	°
	minute	'
	second	"
volume	liter	L
mass	metric ton	t
area	hectare	ha

Table II-7 SI Prefixes

Factor	Prefix	Symbol
$1\,000\,000\,000\,000\,000\,000 = 10^{18}$	exa	E
$1\,000\,000\,000\,000\,000 = 10^{15}$	peta	P
$1\,000\,000\,000\,000 = 10^{12}$	tera	T
$1\,000\,000\,000 = 10^{9}$	giga	G
$1\,000\,000 = 10^{6}$	mega	M
$1000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto[A]	h
$10 = 10^{1}$	deka[A]	da
$0.1 = 10^{-1}$	deci[A]	d
$0.01 = 10^{-2}$	centi[A]	c
$0.001 = 10^{-3}$	milli	m
$0.000\,001 = 10^{-6}$	micro	μ
$0.000\,000\,001 = 10^{-9}$	nano	n
$0.000\,000\,000\,001 = 10^{-12}$	pico	p
$0.000\,000\,000\,000\,001 = 10^{-15}$	femto	f
$0.000\,000\,000\,000\,000\,001 = 10^{-18}$	atto	a

[A] The terms hecto, deka, deci, and centi are to be avoided where possible.

7. Special Calculations using Derived Units:

There are three derived units in the SI used frequently in structural calculations. These units require special understanding on their use. The units are:

Table II-8: Special Units

Quantity	Name	Symbol	Expression
force	newton	N	$N = kg \bullet m/s^2$
pressure, stress	pascal	Pa	$Pa = N/m^2$
energy	joule	J	$J = N \bullet m$

Force: It is important that the distinction between mass (kg) and force (N) be understood. When working in the "inch-pound" (Imperial) system, the quantities for "weight" and "force" are interchangeable. A block of concrete weighing 1000 pounds when placed on a beam produces a force of 1000 pounds. **In the metric system there are separate units for mass (kg) and force (N). The familiar law of physics applies.** (i.e. Force "N" = mass times acceleration due to gravity.) The metric acceleration is 9.807 m/sec^2 (32.2 ft/sec^2 x 0.3048 m/ft.) Mass substitutes for the weight of an object. The mass must be converted to force (by multiplying by 9.807) before computing structural reactions, shears, moments, or internal stresses.

> For example: a simply supported beam 10 meters long with a mass of 231 kg/m would have a total mass of 2310 kg. However, the dead load of the beam used to calculate reactions, shears, moments, etc. would be 231 x 9.807 = 2266 N/m. The distinction between mass and force in structural calculations is very important.

Table II-9 below repeats some of the ASTM E-380 conversion factors for mass and force. The table is intended to provide the designer with a "feel" for the magnitude of metric units as compared to "inch-pound" units. Use of the conversion factors may be necessary for computation during the initial uses of the metric system. However, it is intended that the use of the conversion factors will disappear as designers become familiar with the metric system. Conversion factors to convert pounds directly to newtons are repeated here.

Table II-9: Mass and Force Conversion Factors

Quantity	From Inch-Pound Units	To Metric Units	Multiply by:
mass	pound	kg	0.453 592 4
mass	ton	metric ton (1000 kg)	0.907 184
mass/unit len	plf	kg/m	1.488 16
mass/unit area	psf	kg/m^2	4.882 428
mass density	pcf	kg/m^3	16.018 46
force	lb	N	4.448 222
force	kip	kN	4.448 222
force/unit len	klf	kN/m	14.5939

Stress: The Pascal (Pa) is usually considered the unit of stress. However, the Pascal is not universally accepted as the only unit of stress. Because steel section properties are expressed in millimeters, it is more convenient to express stress in a derivative of Pascals. This is newtons per square millimeter (1 N/mm^2 = 1 MPa).

Energy: Although the joule is a standard metric unit (SI), it is typically not used in structural design. Moments are always expressed in terms of N · m or the derivative kN · m.

Table II-10: Design Conversion Factors

Quantity	From Inch-Pound Units	To Metric Units	Multiply by:
bending moment	ft-lb ft-kip	N • m kN • m	1.355 818 1.355 818
moment of inertia	in^4	mm^4	416 231.4
section modulus	in^3	mm^3	16 387.064

SECTION III: Reference Guides

AASHTO Criteria:

The information contained in this section was developed by a task force of the AASHTO Highway Subcommittee on Geometric Design and was approved by AASHTO November 17, 1992. The AASHTO Task Force on Geometric Design has reviewed the publication *A Policy on Geometric Design of Highways and Streets* (the "Green Book") and identified the following geometric design elements as critical elements in metric conversion.

1. Speed

Design Speed km/h		Running Speed km/h
30	(18.64 mph)	30
40	(24.85 mph)	40
50	(31.07 mph)	47
60	(37.28 mph)	55
70	(43.50 mph)	63
80	(49.71 mph)	70
90	(55.92 mph)	77
100	(62.14 mph)	85
110	(68.35 mph)	91
120	(74.56 mph)	98

2. Lane Width:

Metric Criteria	Actual Feet	Replaces
2.7 m	8.86'	9'
3.0 m	9.84'	10'
3.3 m	10.83'	11'
3.6 m	11.81'	12'

3. Shoulders:

Metric Criteria	Actual Feet	Replaces
0.6 m	1.97'	2'
1.2 m	3.94'	4'
1.8 m	5.91'	6'
2.4 m	7.87'	8'
3.0 m	9.84'	10'
3.6 m	11.81'	12'

4. Vertical Clearance:

Metric Criteria	Actual Feet	Replaces
3.8 m	12.47'	13'
4.3 m	14.11'	14'
4.9 m	16.08'	16'

The 4.9 m value is seen to be the critical value since the federal legislation required Interstate design to have 16 feet vertical clearance. In view of the fact that the Interstate, now virtually complete, is based on this minimum clearance, the metric value should provide this clearance as a minimum. The 4.9 m value accomplishes this objective. Other vertical clearance values are not deemed to be as rigid as this value.

5. Clear Zone:

With two exceptions, the Green Book refers to the Roadside Design Guide for clear zone values. The two critical values are the clear zone for urban conditions and locals and collectors. The Task Force has set the following:

Urban Conditions: 0.5 m (1.64 ft)
Locals/Collectors: 3.0 m minimum (9.84 ft)

6. Curbs:

A. Curb Heights

1. Mountable Curb: 150 mm max. (5.91")
2. Barrier Curb: 225 mm max. (8.86")

B. The definition of high speed/low speed has an impact on where a curb is used.

Low speed: 60 km/h or less design speed
High speed: 70 km/h or more design speed

NOTE: The AASHTO design guide lists "High speed" as 80 km/h or more. This was an error in printing.

7. Sight Distance:

Stopping Sight Distance:

Eye Height	1070 mm (3.51 ft.)
Object Height	150 mm (5.91 in.)
Headlight Height	610 mm (2 ft.)

Passing Sight Distance:

Eye Height	1070 mm (3.51 ft.)
Object Height	1300 mm (4.27 ft.)

8. Horizontal Curvature:

Radius definition shall be used in lieu of degree of curve. For designing new roadway alignments use the radius for curves shown in Table I-4 of this document. When designing a project on an existing road then the old plans shall be converted exactly.

9. Structures:

Long bridges will be those over 60 meters in length.

10. Concrete Reinforcing Steel:

The MDOT adopted the *Interim Recommendations for Specifying Soft Metric Reinforcing Bars* as published by the Concrete Reinforcing Steel Institute in its Engineering Data Report Number 41 © 1995. The ASTM *Hard Metric* standard for reinforcing bars will not be used by the transportation industry. AASHTO has established the *Soft Conversion* for reinforcing bars. Until the new standard is adopted, the MDOT will use the above *Interim Guide.* A copy of the *Interim Recommendations for Specifying Soft Metric Reinforcing Bars* will be furnished upon request to the MDOT Metric Coordinator.

11. Sources:

AASHTO

444 North Capital St. NW, Suite 249, Washington, DC 20001; (888) 227-4860; www.aashto.com

- Guide to Metric Conversion, 1993
- LRFD Bridge Design Specifications, 1994
- LRFD Bridge Design Specifications- SI (Metric), 1997 interim
- Policy on Geometric Design of Highways and Streets, 1994
- Roadside Design Guide, 1996
- Standard Metric Practice Guide, 1991
- Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 1997
- Traffic Engineering Metric Conversion Factors, 1993

AASHTO-AGC-ARTBA

444 North Capital St. NW, Suite 249, Washington, DC 20001; (888) 227-4860; www.aashto.com

- Guide to Standardized Highway Barrier Hardware, 1995

ASTM

1916 Race St., Philadelphia, PA 19103; (215)299-5585

- Standard Specification for Deformed and Plain Billet Steel Bars for Concrete Reinforcement, 1996
- Standard Practice for the Use of Metric (SI) Units in Building Design and Construction, 1991

FHWA

NTIS, 5285 Port Royal Road, Springfield, VA 22161; (703)487-4650

- Geotechnical Metrication Guidelines, 1995

GSA

1090 Vermont Ave., NW, Suite 700, Washington, DC 20005-4905; (202)289-7800

- Metric Design Guide, 1993

IEEE/ASTM

345 East 47th St. New York, NY 10017

- Standard for the Use of the International System of Units (SI); The Modern Metric System, 1997

NIST

NTIS, 5285 Port Royal Rd., Springfield, VA 22161; (703)487-4650

- Interpretation of the SI for the United States and Metric Conversion Policy for Federal Agencies, 1991
- Guide for the Use of the International System of Units, 1995

AASHTOMetrication Clearinghouse

Texas Transportation Institute, 3235 Arizona Ave., Los Alamos, NM 87544; (505)661-0434; FAX (505)661-1707; http://tti.tamu.edu/metric

- Newsletters and reference information on-line.

Mississippi Department of Transportation

Metric Coordinator 85-01, Room 7043, 401 North West Street, P. O. Box 1850, Jackson, MS 39215-1850; (601)359-7685; FAX (601)359-7652; E-mail: mcollier@mdot.state.ms.us

- Metric Criteria: Transportation Projects, 1998 (this document)
- **Mississippi Standard Specifications for Road and Bridge Construction, Metric Edition, 1996** ("red-book"); and Mississippi Supplemental Specifications to the 1996 Standard Specifications for Road and Bridge Construction, Metric Edition, **Traffic Signal and Lighting**, 1996

SECTION IV: Implementation Schedule (MDOT):

The FHWA requires all Federal Highway construction projects be metric only after September 30, 2000. The MDOT has decided that maintaining dual systems, metric for Federal and Imperial (English) for State projects, is impractical; therefore, all activities in the MDOT will be metric only by the FHWA mandate.

The Federal Highway Administration originally required September 30, 1996, as the date when all Federal construction projects were to be metric only. The *National Highway System (NHS)* act of 1995 delayed the mandatory date until September 30, 2000. When this law was passed the Mississippi *Transportation Commission* directed the MDOT to continue metric implementation on schedule. The *Commission* believes too much has been invested to change course now, especially since the requirement did not change, only the date.

There will be some exceptions to the metric only provision. The FHWA allows dual units on Right of Way (ROW) deeds and plats. The FHWA requires dual units on Environmental Documents.

The implementation schedule does not include the metricizing of highway signing. After the FHWA makes the final decision on signing the MDOT implementation schedule will be revised.

The MDOT began awarding metric construction projects in May / June, 1996. During the period from now through September 30, 2000, some MDOT construction projects may be awarded using older Imperial (English) units and others using metric units. After September 30, 2000, MDOT construction project contracts, and other activities, will be metric only. There may be some Imperial (English) construction projects in progress past the year 2000.

The MDOT and the Office of State Aid Road Construction have adopted an official policy concerning *Local Public Agency* (***LPA***) projects. These are highway and street construction projects being accomplished by counties and cities under either the State Aid or Federal Aid (Surface Transportation Program, STP) programs. This policy states:

> All Transportation projects involving *American Association of State Highway and Transportation Officials (AASHTO)* construction practices and standards must be metric after December 31, 1996. Starting from January 1, 1997, all project plans submitted for field-review will be metric only.