METRIC TRAINING

FOR THE TRANSPORTATION INDUSTRY

MODULE III
Road and Bridge Design

A Series of Programs
Offered via the Iowa Communications Network
to prepare Iowa Transportation Personnel
for Implementation
of the International System of Measurement

Sponsored by the Iowa Highway Research Board,
Iowa Department of Transportation
and
IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY
HR-376

ABSTRACT
IHRB PROJECT HR-376

"Metric Training For The Highway Industry", HR-376 was designed to produce training materials for the various divisions of the Iowa DOT, local government and the highway construction industry. The project materials were to be used to introduce the highway industry in Iowa to metric measurements in their daily activities. Five modules were developed and used in training over 1,000 DOT, county, city, consultant and contractor staff in the use of metric measurements.

The training modules developed, deal with the planning through operation areas of highway transportation. The materials and selection of modules were developed with the aid of an advisory personnel from the highway industry. Each module is design as a four hour block of instruction and a stand along module for specific types of personnel. Each module is subdivided into four chapters with chapter one and four covering general topics common to all subjects. Chapters two and three are aimed at hands on experience for a specific group and subject. The modules include:

Module 1 - Basic Introduction to the Use of International Units of Measurement. This module is designed for use by all levels of personnel, primarily office staff, and provides a basic background in the use of metric measurements in both written and oral communications.

Module 2 - Construction and Maintenance Operations and Reporting. This module provides hands on examples of applications of metric measurements in the construction and maintenance field operations.

Module 3 - Road and Bridge Design. This module provides hands on examples of how to use metric measurements in the design of roads and structures.

Module 4 - Transportation Planning and Traffic Monitoring. Hands on examples of applications of metric measurements in the development of planning reports and traffic data collection are included in this module.

Module 5 - Motor Vehicle Enforcement. Examples from Iowa and Federal Motor Vehicle Codes are used as examples for hands on training for the vehicle enforcement type personnel using this module.

Each of the modules utilizes visual aids in the form of video tapes and others that can be projected by an overhead projector or through the use of computer aided methods. The course can be self administered or is best done through the use of a group session and the use of a class leader.

Metric Training for the Transportation Industry
Module 3 - Road & Bridge Design

Table of Contents

Basics

Unit 1 - History and SI Basics

This part of the workshop will introduce you to the basics of SI Metric. Topics covered will include:

- A brief history of the metric system and SI
- The seven SI base units
- Derived units
- Supplemental units
- Prefixes
- Additional units to use with SI

At the end of this unit you will have the opportunity to complete a worksheet which will help you demonstrate your grasp of the metric covered in this part of the workshop.

Brief Metric History

Contrary to many people's beliefs the metric system is not a "new" measurement system. The original metric system was developed in the 1670's by a French Clergyman. In 1795 France officially adopted the Metric System as their system of measurement. Even within the United States the metric system has a lengthy history. Thomas Jefferson and John Quincy Adams were early promoters of the metric system in the U.S. In fact, the metric system has been a legal measurement system in the U.S. since 1866. By 1893 all standard U.S. measures were defined in metric terms. In 1902, Congressional legislation requiring the Federal Government to use metric exclusively was defeated by just one vote. At the General Conference on Weights and Measures held in 1960, a resolution was adopted which officially named the modern version of metric measurement to be the "International System of Units", abbreviated SI.

Motivation to Use SI in the U.S.

In recent decades there have been several efforts to convert the U.S. from the current measurement systems to the metric or SI system. Most of those efforts have met considerable resistance from the general public. However, the metric system has slowly progressed into everyday life in the U.S. Most people are actually already familiar with many metric terms. The following listing provides some examples of "everyday metric" that are already in use in the U.S.

- light bulbs: 100 watt, 75 watt
- electric bill: 800 kWh used

- voltage ratings: 110 volts, 220 volts
- camera film: 35 mm
- beverages: 2-liter bottle of soda
- medicine: 500 mg aspirin
- nutritional label: 10 grams of fat
- athletic events: 100 meter dash, 10K run
- automobile engine sizes: 3.2 liter, 3.8 liter
- radio stations: KGGO - 94.9 MHz, WOI - 90.1 MHz
- skis: 225 centimeter
- time: seconds

The transition to metric usage in the U.S. has been very slow. However, there are several reasons why the U.S. should accelerate the shift to metric usage.

International communication and competitiveness

The myth that the U.S. is a self-sufficient, super-power country is quickly disappearing. We live in a "global" economy. In order to survive and prosper in this global economy, the U.S. must be able to easily trade and communicate with other countries. The U.S. is the only industrialized country (and one of only three countries total) in the world which does not use SI. People in other countries are not familiar with the U.S. system of measurements which makes trade and communication difficult. Trade with other countries is hampered due to the need for translation of measurements, or other countries simply refusing to purchase our non-SI designed products. If the U.S. is to maintain its leadership in the global economy it must seriously consider a rapid change to SI.

Increased Efficiency

Many companies are reluctant to change to SI because of the inefficiencies that will result due to time lost in learning the new system, and getting up to speed with it. In Canada, which converted to SI in the 1970's, companies have actually shown an improved efficiency due to decreased design costs and simplified dimensioning. A few U.S. firms (Otis Elevator and IBM) have also reported similar benefits.

Simplicity

The structure of the metric system, with base units and prefixes designating powers of 10, is a more straight forward system than the English system used in the U.S. Whether a person is discussing length (meters) or mass (kilograms) the prefix names and meanings are consistent. For example in the U.S. there are 12 inches in a foot, 3 feet in a yard, and 5280 feet in a mile. Each factor has different numbers, increasing the likelihood for error between translations. Using metric, when describing larger distances, everything is just a power of 10: 10 mm in a cm, 1000 mm in a m, and 1000 m in a km. Due to the simplified conversions, there is less chance for mathematical errors. In addition to the simplified conversions, because of the use of prefixes with base units there are fewer "names" to learn or get confused. There are also standardized methods for writing the terms, which leads to less confusion over abbreviations.

Recent History of SI in the Federal Government

On July 25, 1991 President George Bush signed Executive Order 12770 which provides guidelines for departments and agencies in the Federal Government to use metric measures to the extent economically feasible by the end of fiscal year 1992 or by such other date as established in consultation with the Secretary of Commerce.

The Department of Commerce requires federal agencies to use metric and to establish target dates for full implementation of the metric system.

The Department of Transportation and the Federal Highway Administration have established the following target dates for implementation of metric: 1994 - conversion of FHWA manuals, documents and publications, 1995 - data collection and reporting in metric, and September 30, 2000 - all Federal lands Highways and Federal-aid construction contracts must be in metric. This last date is the date which is causing the Iowa State Department of Transportation to also convert to the metric system no later than September 30, 2000. (Note: Recent legislation has shifted the date from September 30, 1996 to September 30, 2000.)

Units of Measure For Construction Video - Goals

Understand the base units and common prefixes

Know SI seven base units

- Describe standard for length - meter
- Describe standard for mass - kilogram

Learn about derived units

- Describe force - newton
- Describe pressure/stress - pascal

Learn about additional units

- Describe temperature - degree Celsius
- Describe fluid volumes - liter
- Describe volume - m^3

Unit 1 - History and SI Basics

The following pages contain an outline/guide which should be used as you view the video entitled Units of Measure. Please write any additional notes from the video directly on these sheets.

Units of Measure Video Outline

Le Systeme International d"Unites
(The International System of Units)
Metric system adopted as international standard in 1960
Commonly referred to as SI or SI Metric

Seven Base Units

Length	meter
Mass	kilogram
Time	second
Electric current	ampere
Temperature	kelvin
Amount of matter	mole
Luminous intensity	candela

A closer look at length

Base Unit - meter

Definition of a meter - distance light travels in a vacuum in a time interval of 1/299,792,458 of a second

Symbol for a meter - m

Other length measurements used by Iowa DOT

millimeter
Definition of a millimeter - 1/1000 of a meter
Symbol - mm

kilometer
Definition of a kilometer - 1000 meters
Symbol - km

Area measurements

	Symbol
square meters	m^2
hectare	ha
square kilometers	km^2
square millimeters	mm^2

A closer look at mass

Base unit - kilogram

Definition - set by a specific physical weight (prototype) held at the International Bureau of Weights and measures

Symbol - kg

Other unit of mass

gram
Definition - 1/1000 of a kilogram
Symbol - g

Derived Units

Definition of a derived unit - a unit which is a unique combination of base (or other derived) units which identify a common phenomenon.

Listing of common derived units

frequency	hertz
force	newton
pressure	pascal
energy	joule
power	watt
quantity of electric charge	coulomb
electric potential	volt
electric capacitance	farad
electric resistance	ohm
electric conductance	siemens
magnetic flux	weber
flux density	tesla
inductance	henry
luminous flux	lumen
illumination	lux
radioactivity	becquerel
absorbed dose	gray
dose equivalent	sievert

A closer look at force

unit is the newton

replaces pounds-force in the English system

force = mass x acceleration
newton = kilograms x meter/(square seconds)
$N = kg \cdot m/s^2$

Example using "approximate calculations"
(acceleration is used as 10, which is a rounded number)

$1 \text{ kg} \times 10 \text{ m/s}^2 = 10 \text{ N}$

Other units of force

kilonewton
Definition - 1000 newtons
Symbol - kN

meganewton
Definition - 1,000,000 newtons
Symbol - MN

A closer look at pressure

unit is the pascal

replaces pounds per square inch (PSI) in the English system

pressure = force/area
pascal = newton/(square meter)
$Pa = N/m^2$

Other units of pressure

kilopascal
Definition - 1000 pascals
Symbol - kPa

megapascal
Definition - 1,000,000 pascals
Symbol - MPa

Additional Units

Units that have been approved to be used with SI, even though they are not SI units.

Unit 1 - History and SI Basics

A closer look at temperature

degree Celsius

water freezes = $0^{o}C$ $32^{o}F$
water boils = $100^{o}C$ $212^{o}F$

replaces Centigrade from older metric systems

room temperature = $20^{o}C$
normal body temperature = $37^{o}C$

A closer look at volume

Liter - used for fluid volume

Definition - one cubic decimeter

Symbol - L

one liter is approximately 1 quart + 1/4 cup

Other units of volume

milliliter
Definition - 1/1000 of a liter
Symbol - mL

Other volumes (non-fluid)

	Symbol
cubic meters	m^3
cubic centimeters	cm^3
cubic decimeters	dm^3
cubic millimeters	mm^3

NOTES FOR IOWA DOT

1) Angular measurements do not change and remain in degrees, minutes and seconds. Even though SI standard is the radian.

2) Measurements made relative to ROW takings, railroad agreements and utility construction will be identified in both English and SI.

Visualizing Metric

Length

1 meter is just a little longer than a yard

1 millimeter, which is 0.001 meters, is about the width of the wire in a paper clip

Length of my hand = ____________ mm or _____________ m

My height = _________________ mm or ______________ m

Dimensions of a 8-1/2" x 11" sheet of paper = ___________ mm x ___________ mm

One pace for me = _______________ m

Height Table (Converted to nearest mm)

Ht	mm						
4' 6"	1372	5' 1"	1549	5' 9"	1753	6' 5"	1956
4' 7"	1397	5' 2"	1575	5' 10"	1778	6' 6"	1981
4' 8"	1422	5' 3"	1600	5' 11"	1803	6' 7"	2007
4' 9"	1448	5' 4"	1626	6' 0"	1829	6' 8"	2032
4' 10"	1473	5' 5"	1651	6' 1"	1854	6' 9"	2057
4' 11"	1499	5' 6"	1676	6' 2"	1880	6' 10"	2083
5' 0"	1524	5' 7"	1702	6' 3"	1905	6' 11"	2108
		5' 8"	1727	6' 4"	1930	7' 0"	2134

Mass

1 nickel (5 cents) has a mass of 5 grams

100 pounds is about 45 kilograms

A long ton is about equal to a metric tonne (t) which is equal to a megagram (Mg).

My mass = _______________ kg

Mass table (Converted to nearest 0.1 kg)

wt(lb)	kg						
		130	59.0	190	86.2	250	113.4
75	34.0	135	61.2	195	88.5	255	115.7
80	36.3	140	63.5	200	90.7	260	117.9
85	38.6	145	65.8	205	93.0	265	120.2
90	40.8	150	68.0	210	95.3	270	122.5
95	43.1	155	70.3	215	97.5	275	124.7
100	45.4	160	72.6	220	99.8	280	127.0
105	47.6	165	74.8	225	102.1	285	129.3
110	49.9	170	77.1	230	104.3	290	131.5
115	52.2	175	79.4	235	106.6	295	133.8
120	54.4	180	81.6	240	108.9	300	136.1
125	56.7	185	83.9	245	111.1		

Temperature

Degree Celsius	Equals
177	350 degree oven
100	Water boils (212)
37	Normal body temperature of 98.6
22	room temperature (72)
10	spring or fall day (50)
0	Water freezes (32)
-12	Typical Iowa winter temperature (10)
-18	Zero degrees Fahrenheit (0)
-30	Frigid winter night in Iowa (-22)

Pressure

Auto tire pressure of 28 (PSI) equals roughly 200 000 Pa
or 200 kPa
or 0.2 MPa

Area

A hectare is about 2.5 acres.
A square mile is about 2.5 square kilometers.

Volume

A quart is a little smaller than a liter.
1 teaspoon is about 5 mL.
A concrete mixer truck holds about 7 cubic meters of ready-mix concrete (about 9 cubic yards).
A typical straight truck holds about 8.5 cubic meters of gravel (about 11.5 cubic yards).

Worksheet Review

1. Which of the following metric units is used to express fluid volume?

   A. liter
   B. cubic centimeter
   C. pascal
   D. hectare

2. Which unit of measuring temperature would be used in construction situations?

   A. degree Fahrenheit
   B. degree Centigrade
   C. kelvin
   D. degree Celsius

3. Newton replaces which unit in the English system?

   A. pounds per square inch
   B. pound force
   C. pounds per cubic inch
   D. pound mass

4. Iowa DOT drawings should use which of the following units? (Circle all that apply.)

   A. meter
   B. centimeter
   C. millimeter
   D. megameter

5. On the Celsius scale, water freezes at what temperature?

   A. 32°C
   B. 100°C
   C. 0°C
   D. 0 K

6. Which SI metric unit listed here would be appropriate to use for expressing the volume of concrete or fill?

   A. cubic decimeter
   B. cubic meter
   C. liter
   D. ton

7. Which of the following is the same as 200 meters?

   A. 0.02 km
   B. 2 km
   C. 0.2 km
   D. 20 km

Worksheet Review

8. Which is the same as 3 meters?

A. 0.03 km
B. 3000 mm
C. 300 mm
D. 0.3 km

9. Which of the following represents the longest length?

A. 3.0 m
B. 450 mm
C. 0.05 km
D. 20.0 cm

10. SI refers to:

A. The system interfaces necessary to implement metric in computers.
B. The internationally accepted metric system used today.
C. The governing organization that establishes metric rules and policies.
D. The international strategies that created the first metric system.

11. On the moon, acceleration of a falling object caused by gravity is about 1.7 m/s^2. Using the proper metric unit, what is the gravity force of a two kilogram object?

A. 3.4 pascals
B. 1.7 pascals
C. 3.4 newtons
D. 1.7 newtons

12. Which SI unit replaces PSI in the English measurement system?

A. kg/m^2
B. N
C. Pa
D. N·m

Road Design

Unit 2 - SI Applications in Road Design Activities

This part of the workshop will provide a brief introduction to the basic of converting measurements from English units to SI Metric. The majority of the time in this unit will be dedicated to working sample conversion and SI metric road design problems. Topics covered will include:

- Hard vs. Soft Conversion
- Use of Conversion Tables
- SI Road Design Problems

Types of Conversions

Hard Metric Conversion

original design done in metric (use metric standards)

steps required:
calculate measurement in metric (use conversion factors if "thinking" in English)
select a preferred metric dimension that meets design performances needed

Example: to design a product that needs a bolt.... if this was originally designed in English units you would have selected a 3/4" x 4" hex cap bolt. Determine what standard metric bolt you will want to use in this new metric design.

First determine "equivalent" diameter
1 inch = 25.4 mm
3/4" => (3/4)(25.4) = .75(25.4) = 19.05 mm
closest common (standard) metric diameter screw is 20 mm called an M20

Next determine "equivalent" length

1 inch = 25.4 mm
4" => 4(25.4) = 101.6 mm
closest common (standard) metric length is 100 mm

Metric screw to use would be M20 x 100

Soft Metric Conversion

original design in English (use English Standards)

steps required:
use conversion factors to translate English unit to metric measurement
round measurement to intended precision
examples:

if English design calls for 1 lb use conversion factor and specify 454g (0.454 kg)
if English design calls for 1 qt use conversion factor and specify 0.9463 L

Conversion Factors

When converting English units to SI units you will need to use conversion factors. Conversion tables can come in many different formats. For this workshop we will be using conversion tables that look like this:

Quantity	From	To	Multiply by
Length	ft	m	0.3048
	in	m	25.4×10^{-3}
	yd	m	0.9144
Mass	lbm	kg	0.4536

EXAMPLES:

A. Convert 1000 yards to meters using the conversion table above:

1000 yards x 0.9144 meters/yard = 914.4 meters

B. Convert 5'7" to SI units

First convert 5' to inches... must have all one unit only to convert

So 5 x 12 = 60" plus the 7" == 67"

Now convert the 67" to meters

67 inches x 25.4×10^{-3} m/inch = 1.7018 m => 1.7 m

Road Design Problems

A. A horizontal curve is being designed for a relocated roadway. What it the minimum length of radius required for each of the following design speeds, a maximum rate of superelevation of 8% and a frictional factor of 0.11?

R m (min) = V^2/127[(e max/100 + f maximum)]

1. 80 km/h

2. 100 km/h

3. 110 km/h

B. What length of spiral curve would be required for the 110 km/h curve radius in question A? Round to nearest 5 m.

L m = 0.0702(V^3)/RC where C = 1

C. Calculate the Length of Curve, Tangent and External distances for the 110 km/h curve with a delta angle of 6 degrees.

L = 3.1416 (R) (delta angle)/180
T = R(Tan (1/2 delta))
E = R[(1/Cos(1/2 delta))-1]

D. What is the minimum length of stopping sight distance required to provide adequate distance for design speeds of 100 km/h, a friction factor of 0.28 and a maximum grade of -3%?

$d_2 = V^2/254(f \pm G)$

$d_1 = 0.278t1V$ assume $t_1 = 2.5$ s

E. Passing sight distance is to be designed for a given highway. Calculate the total distance required to complete the pass safely from the equations below.

$D = d_1 + d_2 + d_3 + d_4$

$d_1 = 0.278t_1(V\text{-}m+at_1/2)$ $d_2 = 0.278(vt_2)$

d_3 = 30 to 90 m $d_4 = 2/3\ d_3$

Assume: t_1 = 3-4.5 s, m=5 km/h, a=1, t_2= 9.3-11.3 s, V = 80 km/h

F. The designer of a given horizontal curve desires to use a superelevation transition runoff. What length (nearest 5 m) is required for the runoff to accommodate a 100 km/h design speed, friction factor of 0.4 and a C value of 1.0?
$L = 2.72 f V_D/C$

G. Using the values from Table III-35 (AASHTO Green Book) for crest vertical curves, determine the difference in desirable length required to provide stopping sight distance for the following grades of +2.0% and -2.5% if the designer changes from a 100 km/h to 110 km/h design speed?

Design Speed (km/h)	Assumed Speed for Condition (km/h)	Coefficient of Friction f	Stopping Sight Distance for Design (m)	Rate of Vertical Curvature, K (length (m) per % of A) Computed	Rate of Vertical Curvature, K (length (m) per % of A) Rounded for Design
30	30-30	0.40	29.6-29.6	2.17-2.17	3-3
40	40-40	0.38	44.4-44.4	4.88-4.88	5-5
50	47-50	0.35	57.4-62.8	8.16-9.76	9-10
60	55-60	0.33	74.3-84.6	13.66-17.72	14-18
70	63-70	0.31	94.1-110.8	21.92-30.39	22-31
80	70-80	0.30	112.8-139.4	31.49-48.10	32-49
90	77-90	0.30	131.2-168.7	42.61-70.44	43-71
100	85-100	0.29	157.0-205.0	61.01-104.02	62-105
110	91-110	0.28	179.5-246.4	79.75-150.28	80-151
120	98-120	0.28	202.9-285.6	101.90-201.90	102-202

Table III-35. Design controls for crest vertical curves.

When S<L $L = AS^2/404$
When S>L $L = 2S - 404/A$

H. A minimum length of vertical crest curve is usually defined by the equation: L m = 0.6 V. Calculate the minimum length of curve for a design speed of 100 km/h.

I. You are being asked to revise the length of curve calculated in problem G to allow for passing sight distance for the 110 km/h design speed using the following equations and Table III-36.

Design Speed (km/h)	Minimum Passing Sight Distance for Design (m)	Rate of Vertical Curvature, K, Rounded for Design (length (m) per % of A)
30	217	50
40	285	90
50	345	130
60	407	180
70	482	250
80	541	310
90	605	390
100	670	480
110	728	570
120	792	670

Table III-36. Design controls for crest vertical curves based on passing sight distance.

When S<L $L = AS^2/946$
When S>L $L = 2S - 946/A$

J. An access road connection with the mainline design requires a sag curve be designed. The limiting grades in this case are -2.8% and +0.5% and the design speed is 90 km/h. Using the given information and Table III-37, compute the required desirable length of curve.

Assumed Design Speed (km/h)	Speed for Condition (km/h)	Coefficient of Friction f	Stopping Sight Distance for Design (m)	Rate of Vertical Curvature, K (length (m) per % of A)	
				Computed	Rounded for Design
30	30-30	0.40	29.6-29.6	3.88-3.88	4-4
40	40-40	0.38	44.4-44.4	7.11-7.11	8-8
50	47-50	0.35	57.4-62.8	10.20-11.54	11-12
60	55-60	0.33	74.3-84.6	14.45-17.12	15-18
70	63-70	0.31	94.1-110.8	19.62-24.08	20-25
80	70-80	0.30	112.8-139.4	24.62-31.86	25-32
90	77-90	0.30	131.2-168.7	29.62-39.95	30-40
100	85-100	0.29	157.0-205.0	36.71-50.06	37-51
110	91-110	0.28	179.5-246.4	42.95-61.68	43-62
120	98-120	0.28	202.9-285.6	49.47-72.72	50-73

Table III-37. Design controls for sag vertical curves.

$S < L \quad L = AS^2/(120+3.5S)$

$S > L \quad L = 2S - [(120+3.5S)/A]$

K. What minimum length of sag curve would be allowed in problem J to meet the comfort criteria outlined by AASHTO?

$L\,m = AV^2/395$

L. A drainage site requires obtaining a permanent easement for storm water detention of 1 square mile. How many hectares of easement will you ask the ROW Department to purchase?

M. Bridge clearances noted on last years' inspection record were identified as 14.5 feet. What is the clearance (0.1 m)?

N. The needs study crew has indicated that an existing roadway consists of a 22 foot wide pavement and 8 foot granular shoulders. What metric pavement and shoulder dimensions will you use to connect the existing roadway to you extension?

O. Sketch a typical cross section of a roadway that you might be designing. Include a cut situation on one half and a fill situation on the other side of the roadway. Identify each of the key horizontal and vertical dimensions on the sketch, including any subbase, base and pavement dimensions in international units.

P. You have been assigned a project to design using international units of measure. The End of Project Station (English) from the previous project is 675+50.25. Convert the EOP station to international units and then express both stations as an equation.

Unit 2 - SI Applications in Road Design Activities

Q. Utilizing selected portions of pages from a set of Sioux County Highway 18 plans answer the following questions:

1. Sheet A.01 Title Sheet - What is the total length of the project (Divisions I and II) in meters?

2. Sheet A.01 Title Sheet - Assume that the project is extended through the city of Hull to the East Corporate Line. Estimate the revised End of Project Station for Division II.

3. Sheet B.01 Standard Sections - What is the total volume of granular surfacing to be applied in accordance with Plate 2108? Assume a depth of 155 mm.

What mass of material does this represent in Mg if the material has a mass of 4100 kg/m^3?

4. Sheet B.03 Standard Sections - What is the length of the granular subbase placement in Plate 2211 in kilometers?

LETTING DATE

PCC PAVEMENT - GRADE/NEW
STP-18-1(999)--2C-84

SIOUX CO.

TOTAL SHEETS
83
PROJECT NUMBER
STP-18-1(999)--2C-84
R.O.W. PROJECT NUMBER
STPN-18-1(998)--2J-84
PROJECT IDENTIFICATION NUMBER
95-84999-1

IOWA
DEPARTMENT OF TRANSPORTATION

Project Development Division

PLANS OF PROPOSED IMPROVEMENT ON THE

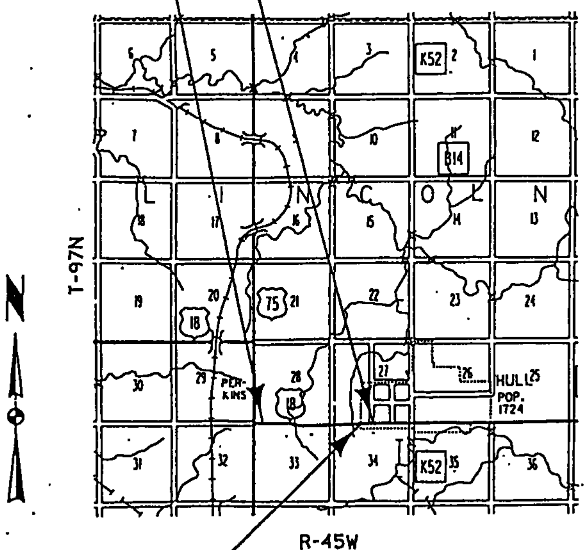
PRIMARY ROAD SYSTEM
SIOUX COUNTY
PCC PAVEMENT - GRADE/NEW

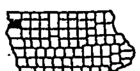
On U.S. 18 from the South Junction of U.S. 75
to Linn St. in the City of Hull

SCALES: As Noted

The Iowa Department of Transportation Metric Standard Specifications for Highway and Bridge Construction, series of 1995, plus current supplemental specifications and special provisions shall apply to construction work on this project.

Value Engineering Saves. Refer to Standard Notation 205-4 on Sheet C.02





LOCATION MAP SCALE
0 1 2 3 4 5
KILOMETERS

INDEX OF SHEETS

105-3
09-27-94

Note: Not all of the sheets listed above are included in the plan for the Metric Plan Reading Course.

PROJECT LENGTH SUMMARY

105-1
09-27-94

DIV.	LOCATION	m	km
1	Rural		
	Sta. 2+43.84 to Sta. 22+69.50	2106.16	
	Net Length of Div. 1	2106.16	
2	Urban		
	Sta. 22+69.50 to Sta. 23+50.00	80.50	
	Net Length of Div. 2	80.50	
	Total Length of Project	2186.66	2.186

METRIC STANDARD ROAD PLANS

105-4
09-27-94

The following Standard Road Plans shall be considered applicable to construction work on this project.

NUMBER	DATE	NUMBER	DATE	NUMBER	DATE
RA-40	06-06-95	RF-3	03-28-95	RH-22	09-27-94
RA-49	06-06-95	RF-5	03-28-95	RH-370	09-27-94
RA-53	06-06-95	RF-14	06-06-95	RH-458	09-27-94
RA-54	06-06-95	RF-19C	12-13-94	RH-50	06-06-95
RA-55	06-06-95	RF-19E	03-28-95	RH-51	06-06-95
RB-3	06-06-95	RF-30A	03-28-95	RH-52	06-06-95
RB-6	06-06-95	RF-30B	03-28-95	RL-1B	12-13-94
RC-16	06-06-95	RF-31	03-28-95	RL-2A	12-13-94
RE-3A	06-06-95	RF-41	03-28-95	RL-7	12-13-94
RF-1	03-28-95	RF-42	03-28-95	RP-1	09-27-94

DESIGN DATA RURAL

101-4

1994 AADT	2900	V.P.D.
2014 AADT	3500	V.P.D.
2014 DHV	196	V.P.H.
TRUCKS	13	%

REVISIONS

JACOB D. RYDELL 98765
REGISTERED PROFESSIONAL ENGINEER IOWA

I hereby certify that this plan was prepared under my supervision and that engineering decisions with regard to the design were made by me or by other duly Registered Professional Engineers under the laws of the State of Iowa.

Name

Iowa Registration No. Date

Iowa Department of Transportation

Project Development Division

AUTHORIZED FOR LETTING

DESIGN ENGINEER

Iowa Registration No. Date

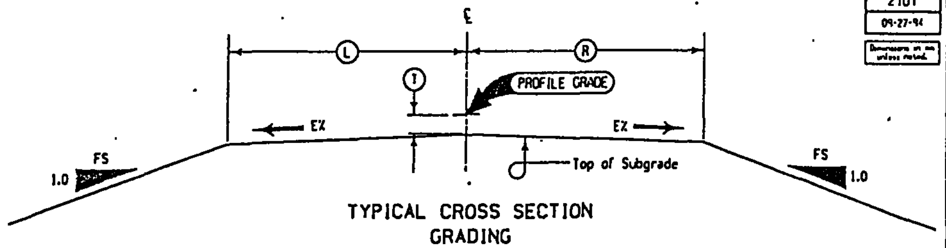
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
APPROVED

FOR THE DIVISION ADMINISTRATOR DATE

DESIGN TEAM Standardization Committee	METRIC	IOWA DOT • OFFICE OF DESIGN	SIOUX COUNTY	PROJECT NUMBER STP-18-1(999)--2C-84	SHEET NUMBER A.01

2101

09-27-94



TYPICAL CROSS SECTION GRADING

Notes:

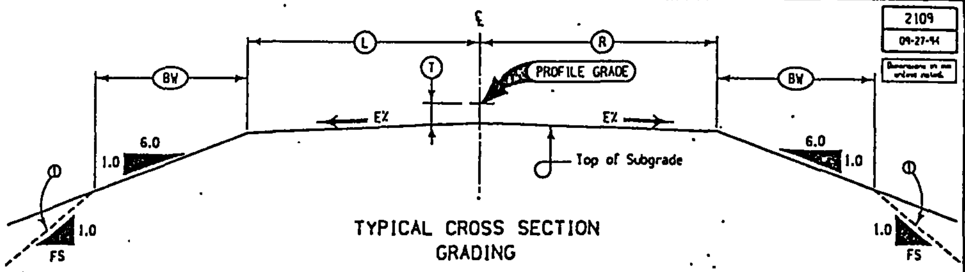
Normal sections shown may be modified appropriately in areas of superelevated curves or other locations specifically designated by the engineer.

See appropriate Typical Sections in this plan for details of ditches and backslopes.

LOCATION			L (m)	R (m)	T (mm)	FS	E%
ROAD IDENTIFICATION	STATION TO STATION						
Harrison Ave. (North)	1016+18.33	1029+00.00 -	6.9	6.9	250	4	2

2109

09-27-94



TYPICAL CROSS SECTION GRADING

Barnroof Section

Notes:

Normal sections shown may be modified appropriately in areas of superelevation curves or other locations specifically designated by the engineer.

See appropriate Typical Sections in this plan for details of ditches and backslopes.

① Refer to Detail Project Plan and Cross Section for specific location of foreslope change.

LOCATION			L (m)	R (m)	T (mm)	BW (m)	FS	E%
ROAD IDENTIFICATION	STATION TO STATION							
U.S. 18	2+43.84	22+69.50	9.0	9.0	400	5.5	3	2

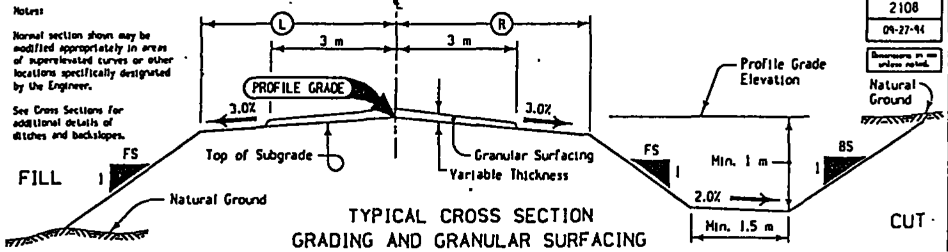
2108

09-27-94

Notes:

Normal section shown may be modified appropriately in areas of superelevated curves or other locations specifically designated by the Engineer.

See Cross Sections for additional details of ditches and backslopes.



TYPICAL CROSS SECTION GRADING AND GRANULAR SURFACING

Granular Surfacing shall be placed as follows:

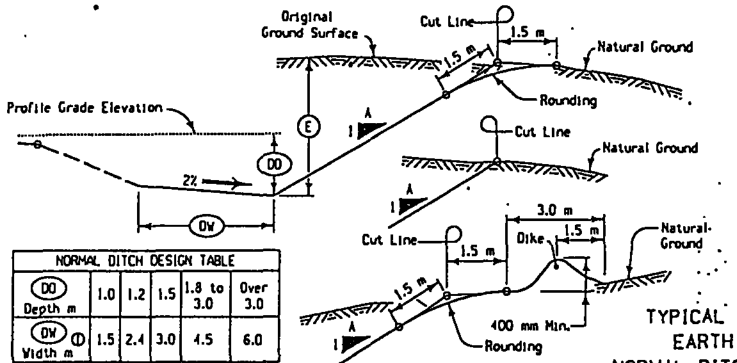
Stage 1 (Grading) Design application rate is 1130 Mg/km.

Stage 2 (Paving) Design application rate is 70 Mg/km.

LOCATION			DIMENSIONS		SLOPES	
ROAD IDENTIFICATION	STATION TO STATION		L (m)	R (m)	FS	BS
Harrison Ave. (South)	1015+30.00	1016+07.63	4.2	4.2	3	2.5

4101

09-27-94



NORMAL DITCH DESIGN TABLE					
DD Depth m	1.0	1.2	1.5	1.8 to 3.0	Over 3.0
DW ① Width m	1.5	2.4	3.0	4.5	6.0

① A 30 m transition should be used between width changes.

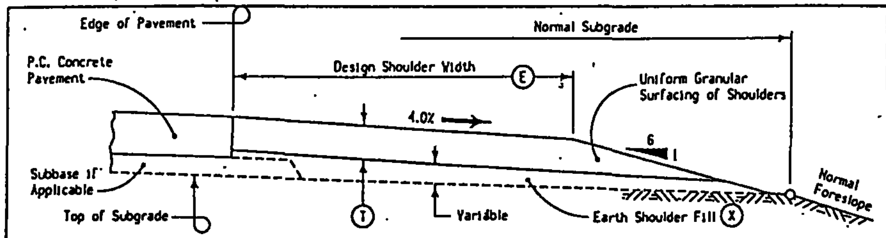
Notes:

For normal conditions, backslopes (A) shall be 2.5 on 1.0 for E depths less than 7.5 m, unless specified otherwise. Refer to detail project plans and cross sections for Ditch Depth or for Special Ditches.

Refer to project plans for locations of areas where rounding of the back slope is not required.

Refer to plans for locations of intercepting ditches. Dike for intercepting ditch shall be made by taking earth from roadway side. Do not excavate back of dike.

TYPICAL CROSS SECTION EARTH EXCAVATION NORMAL DITCH AND BACKSLOPE



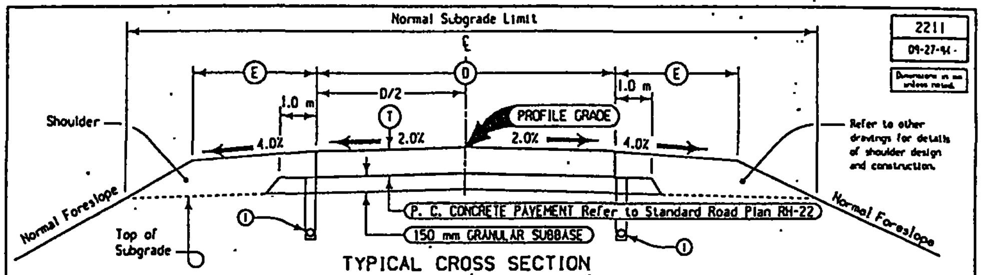
TYPICAL SECTION
TYPE 'A' GRANULAR SHOULDER
Adjacent to PCC Pavement

Notes

Earth Shoulder fill requires approximately (X) cubic meters of excavation, including 60 % for shrinkage, per station.

See Standard Road Plan RH-370 for construction requirements.

LOCATION			(E) m	(T) mm	SIDE	(X) m^3
ROAD IDENTIFICATION	STATION TO STATION					
U.S. 18	2+43.84	22+69.50	2.5	160	Both	111.1



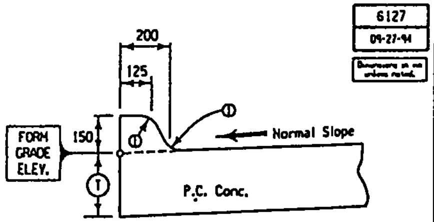
TYPICAL CROSS SECTION
2 LANE ROADWAY With 150 mm GRANULAR SUBBASE

Notes:

Normal sections shown may be appropriately modified for areas specifically designated by the Engineer such as intersections or superelevated curves.

(1) Proposed Subdrain see Standard Road Plan RF-19C

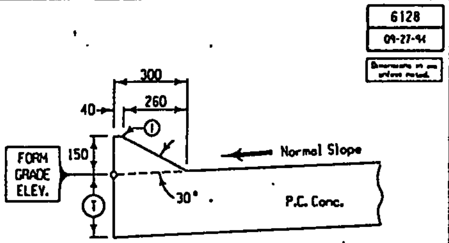
LOCATION			(D) m	(T) mm	(E) m	SHOULDER TYPE
ROAD IDENTIFICATION	STATION TO STATION					
U.S. 18	2+43.84	22+69.50	8.2	250	2.5	Granular



(T) is the thickness specified for pavement

(1) 75 mm radius

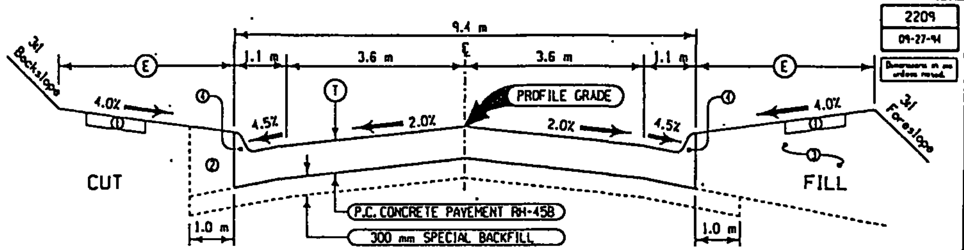
DETAILS OF INTEGRAL 150 mm STANDARD CURB



(T) is the thickness specified for pavement

(1) 50 mm radius

DETAILS OF INTEGRAL 150 mm SLOPED CURB



TYPICAL CROSS SECTION
2 LANE ROADWAY With 1.1 m CURB SECTION

Notes:

Normal section shown may be appropriately modified for areas specifically designated by the engineer such as intersections or, superelevated curves.

Refer to other drawings for details of shoulder design and construction

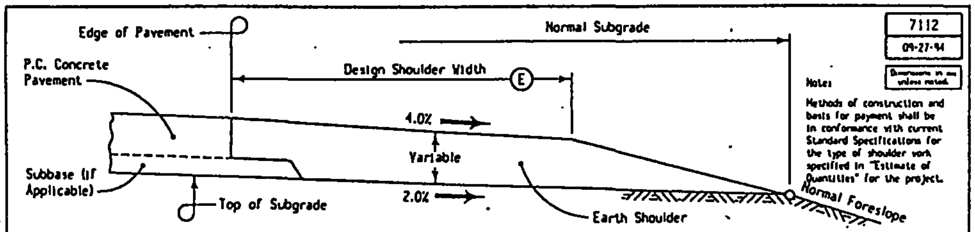
LOCATION			(T) mm	(E) m
ROAD IDENTIFICATION	STATION TO STATION			
U.S. 18	22+69.50	23+50.00	250	5.4

(1) Refer to other drawings for details of shoulder and possible sidewalk construction

(2) Excavate and backfill 1.0 m

(3) Backfill

(4) 150 mm Standard Curb



Notes:

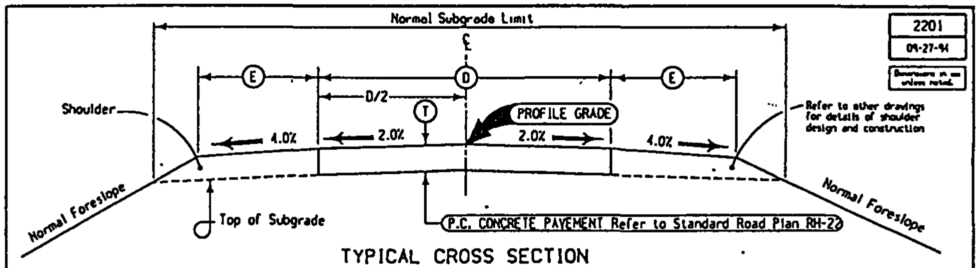
Methods of construction and basis for payment shall be in conformance with current Standard Specifications for the type of shoulder work specified in "Estimate of Quantities" for the project.

(1) Includes ___ % for Shrinkage

LOCATION			(E) m	SIDE
ROAD IDENTIFICATION	STATION TO STATION			
Harrison Ave. (North)	1016+18.33	1029+00.00	1.8	Both

TYPICAL SECTION
EARTH SHOULDER
Adjacent to PCC Pavement

DESIGN QUANTITY RATE Earth Shoulder Material Per Shoulder Per Station	
(E) m	m^3 (1)
1.8	92.50



TYPICAL CROSS SECTION
2 LANE ROADWAY

Notes:

Normal sections shown may be appropriately modified for areas specifically designated by the engineer such as intersections or superelevated curves.

LOCATION			(D) m	(T) mm	(E) m	SHOULDER TYPE
ROAD IDENTIFICATION	STATION TO STATION					
Harrison Ave. (North)	1016+18.33	1029+00.00	7.2	250	1.8	Earth

5. Sheet B.03 Standard Sections - What is the volume of special backfill to be placed in accordance with Plate 2209?

6. Sheet B.03 Standard Sections - Calculate the m^2 of concrete to be placed in accordance with Plate 2201.

7. Sheet C.01 Quantities Estimate - Note the units of measure for the common items of work and the associated level of accuracy.

8. Sheets C.01 and C.02 Estimate Details - Assuming that the seeding will be accomplished between May 21 and July 20, calculate the amount of each seed that will be required for the rural portion of the project.

9. Sheet C.04 Drainage Structures - How many meters of type 1601, 750 mm diameter pipe should be ordered?

ESTIMATED PROJECT QUANTITIES

100-18
09-27-94

CONSTRUCTION USE ONLY	ITEM CODE	ITEM	UNIT	QUANTITIES ESTIMATED DIVISION 1	QUANTITIES ESTIMATED DIVISION 2	QUANTITIES ESTIMATED TOTAL	QUANTITIES AS BUILT DIVISION 1	QUANTITIES AS BUILT DIVISION 2
	2101-0850001	Clearing and Grubbing	ha	0.50	0	0.50		
	2102-0425050	Selected Backfill, Soil	m3	13637	0	13637		
	2102-0425072	Backfill Special	Mg	0	1039	1039		
	2102-2710070	Excavation, Class 10, Roadway and Borrow	m3	95993	1116	97109		
	2102-2712015	Excavation, Class 12, Boulders	m3	35	0	35		
	2102-4560000	Locating Tile Lines	ms	10	0	10		
	2108-5025000	Overhaul	m3ms	347437	0	347437		
	2111-8174100	Granular Subbase	m2	20662	0	20062		
	2121-7425010	Granular Shoulders, Type A	Mg	4187	0	4187		
	2123-7450020	Shoulder Finishing, Earth	m	2476	160	2636		
	2301-4875006	Median, P.C. Concrete, 150 mm	m2	15	0	15		
	2301-5162310	Pavement, Standard or Slip Form P.C. Concrete, Class C, 260 mm	m2	25170	1539	26709		
	2301-6911722	Portland Cement Concrete Pavement Samples	LS	0.96	0.04	1		
	2312-8260050	Granular Surfacing on Road, Class A Crushed Stone	Mg	138	0	138		
	2401-6745650	Removal of Existing Structures	LS	1	0	1		
	2402-0425031	Backfill, Granular	Mg	0	11	11		
	2402-2720100	Excavation, Class 20, For Roadway Pipe Culvert	m3	23	0	23		
	2416-0100084	Aprons, Concrete, 2100 mm Dia.	Each	2	0	2		
	2416-0102088	Aprons, Concrete Arch, 2200 mm x 1350 mm	Each	2	0	2		
	2416-1180084	Culvert, Concrete Roadway, Pipe, 2100 mm Dia.	m	37.8	0	37.8		
	2416-1200088	Culvert, Concrete Arch Roadway Pipe, 2200 mm x 1350 mm	m	25.4	0	25.2		
	2422-0360018	Aprons, Unclassified, 450 mm Dia.	Each	12	0	12		
	2422-0360024	Aprons, Unclassified, 600 mm Dia.	Each	2	0	2		
	2422-0360030	Aprons, Unclassified, 750 mm Dia.	Each	2	0	2		
	2422-1722018	Culvert, Unclassified Entrance Pipe, 450 mm Dia.	m	94.3	0	94.3		
	2422-1723024	Culvert, Unclassified Roadway Pipe, 600 mm Dia.	m	17.6	0	17.6		
	2422-1723030	Culvert, Unclassified Roadway Pipe, 750 mm Dia.	m	25.0	0	25.0		
	2502-8212014	Subdrain, Longitudinal, 100 mm Dia.	m	2192.3	90.2	2282.5		
	2502-8220105	Subdrain Outlet As Per Plan	Each	0	2	2		
	2502-8220196	Subdrain Outlet RF-19E	Each	27	0	27		
	2503-4450030	Intake, RA-40	Each	0	1	1		
	2503-4625290	Utility Access, RA-49	Each	0	1	1		
	2503-7275006	Sewer 100 D Storm, 375 mm Dia.	m	0	19.2	19.2		
	2510-6745850	Removal of Old Pavement	m2	14787	1403	16190		
	2511-6745900	Removal of Sidewalk	m2	0	25	25		
	2511-7526004	Sidewalk, P.C. Concrete, 100 mm	m2	0	29	29		
	2515-2475006	Drives, P.C. Concrete, 150 mm	m2	0	63	63		
	2515-6745600	Removal of Drives	m2	0	24	24		
	2518-6890031	Road Closure (Rural), Permanent, RE-3A	Each	1	0	1		
	2520-3350010	Field Laboratory	Each	0.96	0.04	1		
	2520-3350015	Field Office	Each	0.96	0.04	1		
	2525-2638030	Silt Fence	m	64	0	64		
	2525-2638031	Silt Fence for Ditch Checks	m	407	0	407		
	2526-8285000	Construction Survey	LS	0.96	0.04	1		
	2527-9263110	Painted Pavement Marking	m	5210	17	5227		
	2528-8445110	Traffic Control	LS	0.96	0.04	1		
	2533-4980005	Mobilization	LS	0.96	0.04	1		
	2538-6975110	Sealing Wells	Each	1	0	1		
	2601-2632100	Fertilizing	ha	5	0	5		
	2601-2634100	Mulching	ha	5	0	5		
	2601-2642100	Stabilizing Crop Seeding and Fertilizing	ha	15.6	0	15.6		
	2601-2642120	Stabilizing Crop Seeding and Fertilizing (Urban)	ha	0	1	1		

For Additional Estimate Ref. Info.
Refer to Sheet No. C.02

For Standard Notes
Refer to Sheet No. C.02

For Traffic Control Plan
Refer to Sheet No. C.03

For Pollution Prevention Plan
Refer to Sheet No. C.03

ESTIMATE REFERENCE INFORMATION

100-4
09-27-94

Data listed below is for informational purpose only and shall not constitute a basis for any extra work orders.

ITEM CODE	DESCRIPTION
2102-0425050	Refer to Tab. 103-3 on Sheet No. C.05.
2102-2710070	A. Template quantities include 6223 cu. meters of "C-3" unsuitable material to be used in the roadway embankment. B. Template quantities also include material for earth shoulder fill back of curb and for obliteration of the old railroad embankment from Sta. 8+25 to Sta. 17+25. C. Item includes 2290 cu. meters of material for earth shoulders adjacent to Harrison Ave. pavement, but is not included in template quantities.
2108-5025000	Item calculated by assuming a center of mass of the borrow area. Center of mass location for Borrow Area "A" is shown on Sheet No. R.01.
2111-8174100	Estimated at 2.16 Megagrams per cu. meter.
2121-7425010	A. Item is for 141.39 meters of 1.8 meter shoulder and 3960.8 meters of 2.5 meter shoulder. B. Item requires approximately 4531 cu. meters of earth shoulder fill. Material is to be obtained from Borrow "A" or within R.O.W. as directed by the Engineer.
2123-7450020	A. Item is for 2476.21 meters of 1.8 meter shoulder on Harrison Ave. and 160 meters of 3.0 meter shoulder back of curb. B. The earth shoulder fill material is included in the Class 10 Excavation bid item.
2301-4875006	A. Item is for island at the intersection of U.S.18 with Harrison Ave. B. Granular backfill placed beneath the median pavement is to be included in the cost of this item.
2301-5162310	A. Item requires "CD" joints. B. Transverse joint between existing ACC resurfacing over PCC pavement and proposed PCC pavement to be a "B" joint. Transverse joint between existing PCC pavement and proposed PCC pavement to be a "RD" joint. C. Transverse joints shall not be skewed in Div. 2. D. Transverse grooving will not be required in Div. 2. E. Class 3 aggregate durability required.
2312-8260050	A. Item includes 45 megagrams for Points of Private Access (Tab. 102-1 on Sheet No. C.06) and 93 megagrams for local roads. B. Material shall be spread in accordance with Section 2315 of the 1995 Standard Specifications.
2401-6745650	For location and details refer to Tab. 110-2 on Sheet No. C.06. Disposal as per Standard Notation 213-1.

ROADWAY DESIGN

PROFESSIONAL ENGINEER · IOWA ·

I hereby certify that this plan was prepared under my supervision and that engineering decisions with regard to the design were made by me or by other duly Registered Professional Engineers under the laws of the State of Iowa.

Name

Iowa Registration No. Date

09-27-94 — 201-4

The contractor is encouraged to take full advantage of specification 1105.15 - Value Engineering Incentive Proposal. A pamplet and conceptual proposal form will be available at the preconstruction conference.

09-27-94 — 212-1

Sounding and test boring data shown on plans were accumulated for designing and estimating purposes. Their appearance on the plan does not constitute a guarantee that conditions other than those indicated will not be encountered.

09-27-94 — 212-2

Material listed within the plans as "unsuitable" is included in the template for class 10 excavation and is shown to indicate the location and distribution.

09-27-94 — 213-1

It shall be the contractor's responsibility to provide waste areas or disposal sites for excess material (excavated material or broken concrete) which is not desirable to be incorporated into the work involved on this project. No payment for overhaul will be allowed for material hauled to these sites. No material shall be placed within the right-of-way, unless specifically stated in the plans or approved by the engineer.

09-27-94 — 213-2

The contractor's attention is directed to the following consideration in regard to removal and replacement of topsoil in borrow areas:
Quantities estimated for topsoil are calculated on the basis of a uniform removal of topsoil to a depth of 0.3 meters. The material removed is to be spread uniformly to a minimum depth of 0.2 meters over the borrow area upon completion of excavation work.

09-27-94 — 213-3

All borrow areas, stockpile areas, haul roads and areas used for equipment on this project will require subsoil tillage to an average depth of 0.4 meters to 0.5 meters prior to placement of topsoil and/or stabilizing crop seeding. Such tillage shall be accomplished on maximum of one meter centers and at right angles to the finished slope of the borrow.

Equipment used to accomplish the tillage shall be equipped with an arrowhead-type shoe so as to provide lateral displacement and limit the movement of the subsoil to the surface. It shall be approved by the Engineer for the use intended. This work will be considered incidental to other work on the project and no payment will be allowed.

It is intended that following subsoil tillage, the area remains in a "loosened" condition. Additional compaction or the operation of heavy equipment, other than required for topsoil placement and shaping shall not be allowed on areas which have received subsoil tillage.

09-27-94 — 213-4

The contractor shall apply necessary moisture to the construction area and haul roads to prevent the spread of dust. Refer to Article 1107.07 or the current Standard Specifications for additional details.

09-27-94 — 221-3

Estimated quantity for new concrete pavement includes all integral curb, all street returns and special areas of repairs to connecting pavements.

09-27-94 — 221-4

In order to avoid any unnecessary surface breaks or premature spalling, the contractor is cautioned to exercise extreme care when performing any of the necessary saw cutting operations for the proposed pavement removal.

03-28-95 — 222-1

Special care shall be taken when forming at intersections so that the profiles shown on the cross sections and the elevations shown on the Resident Engineer's 1:100 or 1:250 scale plans are obtained. Short lengths of forms or flexible forms may be necessary at these locations.

09-27-94 — 223-17

Existing PCC pavement shall be recycled into granular subbase. Excess material shall become the property of the contractor and disposed of as per Standard Notes 213-1. Virgin material shall be furnished for any shortage of recycled material required to reach the plan quantity and shall be paid for at contract unit price. The estimated quantity is based on 2150 kilograms per cubic meter in-place density.

09-27-94 — 232-5

The contractor shall not disturb desirable grass areas and desirable trees outside the construction limits. The contractor will not be permitted to park or service vehicles and equipment or use these areas for storage of materials. Storage, parking and service area(s) will be subject to the approval of the resident engineer.

09-27-94 — 232-8

The top 150 millimeters of the disturbed areas shall be free of rock and debris and shall be suitable for the establishment of vegetation, subject to the approval of the Engineer.

09-27-94 — 241-1

Road contractor is to use due caution in working over and around all tile lines. Breaks in the tile line due to the contractor's carelessness are to be replaced at his expense without cost to the State of Iowa. Any tile lines broken or disturbed by our cut lines will be replaced as directed by the engineer in charge of construction and at the State of Iowa's expense.

09-27-94 — 251-1

The contractor shall be responsible to maintain access to individual properties during construction.

Relocated access shall be completed to individual properties prior to removal of existing access.

If the permanent access cannot be completed prior to removal of the existing access, the contractor shall provide and maintain an alternate access. Temporary Granular Surfacing will be paid for as a contract item or by extra work.

09-27-94 — 251-3

A plan for stage construction of local accesses which are required to remain open to traffic during construction shall be submitted by the contractor for approval by the engineer.

09-27-94 — 251-5

On all new or reconstructed pavements, the location of "NO PASSING" zone lines shall be located in the field. The locations of the proposed "NO PASSING" zone lines shown on the pavement marking tabulation is for estimating quantities only.

ESTIMATE REFERENCE INFORMATION

100-4
09-27-94

Data listed below is for informational purpose only and shall not constitute a basis for any extra work orders.

ITEM CODE	DESCRIPTION
2402-0425031	A. Quantity is for storm sewer under pavement. B. For location and details refer to Tab. 104-5B and Detail HD-9 on Sheet No. M.01.
2422-0360018	Item is for entrance pipes.
2502-8212014 2502-8220105 2502-8220196	For location and details refer to Tab. 104-9 on Sheet No. C.05.
2502-8220105	Refer to Intake Outlet Detail on Standard Road Plan RF-19C.
2503-4450030 2503-4625290	Refer to Tab. 104-5A on Sheet No. M.01.
2503-7275006	Refer to Tab. 104-5B on Sheet No. M.01.
2510-6745850	A. For location refer to Tab. 110-1 on Sheet No. C.06. B. Item requires 35.6 meters of full depth sawcut. C. Item requires complete removal of A.C.C. to P.C.C. surface. D. All A.C.C. shall be salvaged and used on the project as granular shoulders or special backfill for subgrade treatment. E. Old P.C.C. pavement shall be salvaged and used on the project as granular subbase.
2511-6745900	A. For location refer to Tab. 110-5 on Sheet No. C.06. B. Disposal shall be as per Standard Notation 213-1.
2511-7526004	For location refer to Detail 6105 on Sheet No. C.06.
2515-2475006	For location and details refer to Tab. 102-3 on Sheet No. C.06.
2515-6745600	A. For location and details refer to Tab. 110-8 on Sheet No. C.06. B. Disposal shall be as per Standard Notation 213-1.
2518-6890031	Item is to be placed on Harrison Ave., 27 meters Lt. of Sta. 1020+45 (O.R.).
2525-2638030 2525-2638031	For location and details refer to Tabs. 100-17 and 100-18 on Sheet No. C.06 and Standard Road Plan RC-16. Exact locations to be as directed by the engineer to minimize erosion and water pollution.
2527-9263110	For location and details refer to Tab. 108-22 on Sheet No. C.07 and Typicals on Sheets No. C.07 and C.08.
2538-6975110	Item is for well located 20 meters Lt. of Sta. 11+05. For details, refer to Design Detail Sheet 560-1 on sheet no. U.01.
2601-2634100 2601-2642100 2601-2642120	Fertilizer: Rate--500 kg of 13-13-13 or equivalant chemically combined commercial fertilizer per hectare.
2601-2632110 2601-2634100	Areas disturbed but not seeded with stabilizing crop by September 30 shall be scarified to a 75 mm depth, fertilized and muched. All mulch to be consolidated into the soil with the mulch stabilizer.
2601-2634100	Mulch Rate - 3.5 megagrams of dry cereal straw per hectare.

ESTIMATE REFERENCE INFORMATION

100-4
09-27-94

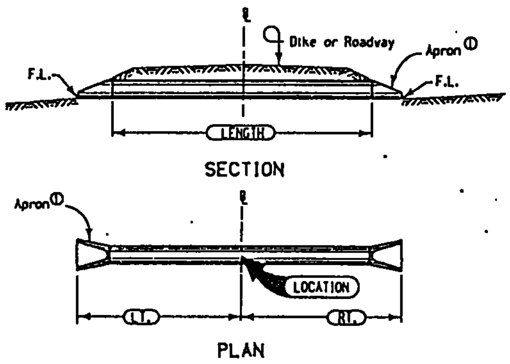
Data listed below is for informational purpose only and shall not constitute a basis for any extra work orders.

ITEM CODE	DESCRIPTION
2601-2642100	Included for all rural areas as designated by the engineer. Seed Mixture: (Rural) Spring--March 1 to May 20 Oats 72 kg per hectare Annual Ryegrass 28 kg per hectare Red Clover 6 kg per hectare Timothy 6 kg per hectare Summer--May 21 to July 20 Oats 108 kg per hectare Annual Ryegrass 39 kg per hectare Red Clover 6 kg per hectare Timothy 6 kg per hectare Fall--July 21 to September 30 Oats 72 kg per hectare Annual Ryegrass 28 kg per hectare Red Clover 6 kg per hectare Timothy 6 kg per hectare
2601-2642120	Included for all urban areas of the right of way as designated by the engineer. Seed Mixture: (Urban) Spring--March 1 to May 20 Annual Ryegrass 28 kg per hectare Bluegrass, Ky (Park) 17 kg per hectare Perennial Ryegrass 17 kg per hectare Summer--May 21 to July 20 Annual Ryegrass 28 kg per hectare Bluegrass, Ky (Park) 17 kg per hectare Perennial Ryegrass 17 kg per hectare Fall--July 21 to September 30 Annual Ryegrass 28 kg per hectare Bluegrass, Ky (Park) 17 kg per hectare Perennial Ryegrass 17 kg per hectare

DRAINAGE STRUCTURE BY ROAD CONTRACTOR

104-3
09-27-94
* Not a bid item

LOCATION	TYPE	SIZE mm	KIND OF PIPE	LENGTH NEW CONST. m	BEDDING CLASS	DESIGN COVER (H)	CAMBER m	APRON NO. Inlet	APRON NO. Outlet	ADAPTORS* RF-2 Type	ADAPTORS* RF-2 No.	CONNECT PIPE JOINT* RF-14 Type	CONNECT PIPE JOINT* RF-14 No.	FLOW LINE ELEVATIONS Lt.	FLOW LINE ELEVATIONS Rt.	FLOW LINE ELEVATIONS Other	DIMENSIONS m Total Lt.	DIMENSIONS m Total Rt.	DIMENSIONS m Extensions Lt.	DIMENSIONS m Extensions Rt.	SKEW AHEAD Degrees Lt.	SKEW AHEAD Degrees Rt.	DIKE Lt. / Rt.	DIKE Location Station	DIKE Top Elevation	DIKE Type	CLASS 20 m³	EMBANK-MENT IN PLACE m³	REMARKS
8+78.00	1101	2100	100 D	37.8	C	2.30		1	1			3	6	437.80	438.00		21.6	21.6				15					15		
20+50.00	1101	(1)	100 D	25.4	C	1.24		1	1			3	6	436.00	436.50		16.1	14.3									8		(1) 2200 mm x 1350 mm Conc. Arch Pipe
1015+93.00	1601	750	Uncl.	25.0	C	1.50		1	1					441.60	441.20		11.3	13.7									--		
1016+40.00	1601	600	Uncl.	17.6	C	1.40		1	1					441.80	441.60		8.5	9.1									--		



1101
09-27-94
Dimensions in mm unless noted.

Notes:

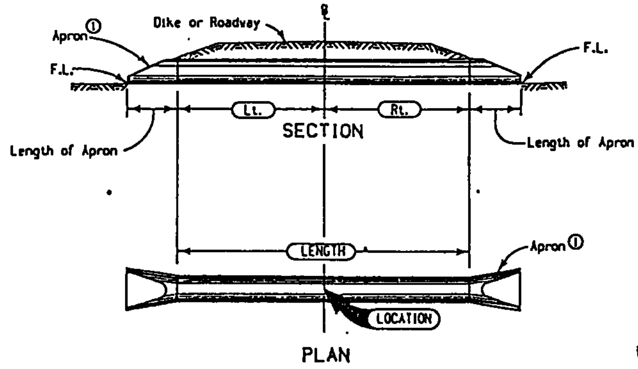
℄ shall be ℄ of roadway, dike, survey, or other) as detailed on plans.

Skew angle is the angle which one end of the pipe is ahead (by stationing) of line perpendicular to the ℄ (example skew Rt. ahead 30°).

Refer to tabular listing and other plans for additional information.

① See Standard Road Plan RF-3 for concrete or RF-5 for metal.

PIPE CULVERT



1601
09-27-94
Dimensions in mm unless noted.

Notes:

℄ shall be ℄ of roadway, dike, survey, or other) as detailed on plans.

Skew angle is the angle which one end of the pipe is ahead (by stationing) of a line perpendicular to the ℄ (example skew Rt. ahead 30 degrees).

Refer to tabular listings and other plans for additional information.

The outer three joints are to be connected when the concrete option is used.

① See Standard Road Plan RF-3 for concrete or RF-5 for metal.

UNCLASSIFIED PIPE CULVERT

HYDRAULIC DESIGN

I hereby certify that this plan was prepared under my supervision and that engineering decisions with regard to the design were made by me or by other duly Registered Professional Engineers under the laws of the State of Iowa.

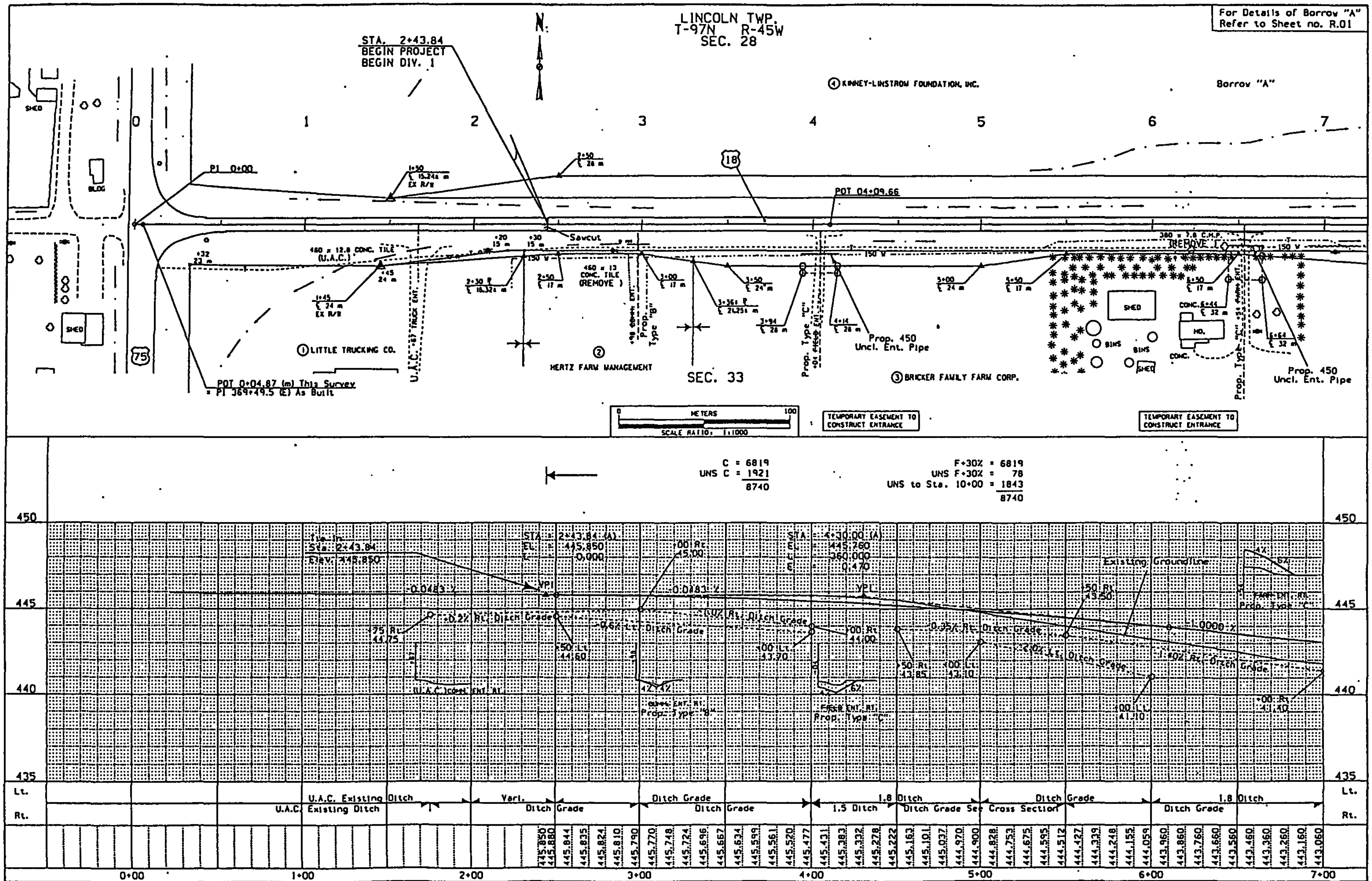
Name

Iowa Registration No. Date

DESIGN TEAM Standardization Committee	METRIC	IOWA DOT • OFFICE OF DESIGN	SIOUX COUNTY	PROJECT NUMBER STP-18-1(999)--2C-84	SHEET NUMBER C.04

10. Sheet D.01 Plan and Profile - What volume of class 10 and unsuitable material is identified for excavation in the balance represented on this page?

11. Sheet D.01 Plan and Profile - What are the elevations of the beginning and end of the special ditch (left side) between stations 5+00 and 6+00?



DESIGN TEAM Standardization Committee	METRIC	IOWA DOT ♦ OFFICE OF DESIGN	SIOUX COUNTY	PROJECT NUMBER STP-18-1(999)--2C-84	SHEET NUMBER D.01

Bridge Design

Unit 3

Unit 3 - SI Applications in Bridge Design Activities

Introduction:

The bridge structures area is one that can cause serious problems in the conversion of existing inch-pound (English) values to international units. The problem stems from the fact that the conversion can seem deceptively simple because most measurements have implied, not expressed, tolerance. Many of these products are identified in easy-to-use nominal sizes, rather than actual sizes. Designers working in structural design have an intuitive knowledge of allowable tolerances in measurements that they use daily and know how the difference between nominal and actual sizes effects the product. Remember the following points when converting and rounding to metric units.

1. Conversion should be performed by experienced professionals. Any Automated conversion program should be used with care.
2. Understand the allowable tolerance for the measurements you are converting.
3. Always convert with the end application or us in mind. Remember, dimensional tolerance on the job are rarely less than a few millimeters and that it is considerably easier for field personnel to measure in 10 mm increments.
4. The most common conversion error is under-rounding which implies more precision than is inherent in the inch-pound number. If your linear conversions are accurate to 0.1 mm or even 1 mm, you are probably doing them incorrectly. Any dimension over a few inches, can usually be rounded to the nearest 5 mm and any dimension over a few feet, can be rounded to the nearest 10 mm.

Hard Conversion Concerns:

Concrete strength is one of the areas that can result in design problems associated with hard conversion of values. Some agencies have converted 4000 psi concrete to 30 MPa. A 30 MPa concrete soft converts to 4350 psi concrete - nearly 9% higher than the old design strength. The rounding results in concrete that may not have the same strength properties as originally tested. This type of problem is under consideration by the ACI organization. A compromise is the use of at least two and more commonly used three significant digits to create the value of 3.45 MPa.

Example Problems

A. A three span bridge was originally designed in English units with span lengths of 30'-6", 39'-0" and 30'-6" for a total length of 100'-0".
   1. Determine the length of the bridge by soft converting each span and by converting the entire length.
   2. Is there a difference in the results and if so what is the significance?

B. Concrete was originally designed for a compressive strength of 4000 psi. If this is hard converted to international units and the concrete is redesigned, will the strength requirement increase or decrease and by what amount?

C. A reinforced concrete section requires 4.0% steel area per m^2. Using the tables on the following page, determine:

1. Number of 10M bars to be placed per m^2:

2. Number of 30M bars to be placed per m^2:

D. You are being asked to design several culverts for an upcoming project. Utilizing culvert standard MRCB-1800-1-95 determine the following quantities:

1. Volume of concrete required to build the barrel section of culvert 20 m in length, 1800 mm in width and 900 mm in height and under a fill height of 4300 mm.

2. What mass of steel is required for the culvert barrel identified in question 1?

3. If the height of fill is increased to 6500 mm, what difference will result in the mass of steel required?

ASTM A615 CHART FOR REINFORCING STEEL BARS

Inch-Pound Bar Size Designation	Nominal Weight lb./ft. (kg/m)	Nominal Dimensions: Diameter in. (mm)	Nominal Dimensions: Cross Sectional Area in² (mm²)
#3	0.376 (.560)	0.375 (9.5)	0.11 (71)
#4	0.668 (.994)	0.500 (12.7)	0.20 (129)
#5	1.043 (1.552)	0.625 (15.9)	0.31 (200)
#6	1.502 (2.235)	0.750 (19.1)	0.44 (284)
#7	2.044 (3.042)	0.875 (22.2)	0.60 (387)
#8	2.670 (3.974)	1.000 (25.4)	0.79 (510)
#9	3.400 (5.060)	1.128 (28.7)	1.00 (645)
#10	4.303 (6.404)	1.270 (32.3)	1.27 (819)
#11	5.313 (7.907)	1.410 (35.8)	1.56 (1006)
#14	7.65 (11.39)	1.693 (43.0)	2.25 (1452)
#18	13.60 (20.24)	2.257 (57.3)	4.00 (2581)

ASTM A615M CHART FOR REINFORCING STEEL BARS

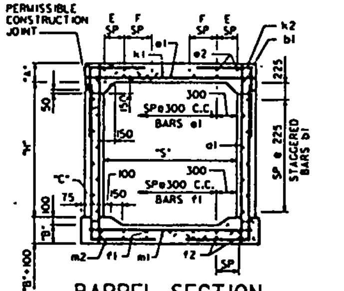
Metric Bar Size Designation	Nominal Mass kg/m	Nominal Dimensions: Diameter mm	Nominal Dimensions: Cross Sectional Area mm²	Comparison To A615
10M	0.785	11.3	100	20% < #4
15M	1.570	16.0	200	SAME AS #5
20M	2.355	19.5	300	6.8% > #6
25M	3.925	25.2	500	1.3% < #8
30M	5.495	29.9	700	9% > #9
35M	7.850	35.7	1000	0.6% < #11
45M	11.775	43.7	1500	3.5% > #14
55M	19.625	56.4	2500	3% < #18

VARIABLE DIMENSIONS AND QUANTITIES FOR BARREL SECTIONS

DIMENSIONS							DIMENSIONS																		
							a1			b1			e1			e2				f1			f2		
																	SPACING								
FILL	S	H	A	B	C	*D	SIZE	SP	L	SIZE	SP	NO.	SIZE	SP	NO.	SIZE	E	F	NO.	SIZE	SP	NO.	SIZE	SP	NO.
0	1800	900	255	255	230	140	15	140	1380	15	225	8	15	300	5	15	410	320	6	15	300	7	15	410	4
300	1800	900	270	255	230	140	15	140	1400	15	225	8	15	300	5	15	380	-	4	15	300	7	15	410	4
600	1800	900	205	255	230	140	15	140	1330	15	225	8	15	300	5	15	380	-	4	15	300	7	15	380	4
900-2100	1800	900	205	255	230	210	15	280	1330	15	225	8	15	300	5	15	300	-	4	15	300	7	15	330	4
2400-3000	1800	900	205	255	230	210	15	280	1330	15	225	8	15	300	5	15	280	-	4	15	300	7	15	300	4
3300-3900	1800	900	205	255	230	140	15	140	1330	15	225	8	15	300	5	15	280	-	4	15	300	7	15	300	4
4200-4800	1800	900	205	255	230	140	15	140	1330	15	225	8	15	300	5	15	280	-	4	15	300	7	15	300	4
5100-6000	1800	900	205	255	230	210	15	210	1330	15	225	8	15	300	5	15	280	-	4	15	300	7	15	300	4
6300-7500	1800	900	205	255	230	140	15	140	1330	15	225	8	15	300	5	15	330	-	4	15	300	7	15	330	4
0	1800	1200	255	255	230	140	15	140	1680	15	225	12	15	300	5	15	410	320	6	15	300	7	15	410	4
300	1800	1200	270	255	230	140	15	140	1700	15	225	12	15	300	5	15	380	-	4	15	300	7	15	410	4
600	1800	1200	205	255	230	140	15	140	1630	15	225	12	15	300	[illegible]	15	360	-	4	15	300	7	15	380	4
900-2100	1800	1200	205	255	230	180	15	180	1630	15	225	12	15	300	5	15	300	-	4	15	300	7	15	300	4
2400-3000	1800	1200	205	255	230	180	15	180	1630	15	225	12	15	300	5	15	280	-	4	15	300	7	15	300	4
3300-3900	1800	1200	205	255	230	140	15	140	1630	15	225	12	15	300	5	15	280	-	4	15	300	7	15	280	4
4200-4800	1800	1200	205	255	230	140	15	140	1630	15	225	12	15	300	5	15	280	-	4	15	300	7	15	280	4
5100-6000	1800	1200	205	255	230	210	15	210	1630	15	225	12	15	300	5	15	280	-	4	15	300	7	15	280	4
6300-7500	1800	1200	205	255	230	140	15	140	1630	15	225	12	15	300	5	15	300	-	4	15	300	7	15	330	4
0	1800	1500	255	255	230	140	15	140	1980	15	225	14	15	300	5	15	380	360	6	15	300	7	15	410	4
300	1800	1500	270	255	230	140	15	140	2000	15	225	14	15	300	5	15	410	-	4	15	300	7	15	410	4
600	1800	1500	205	255	230	140	15	140	1930	15	225	14	15	300	5	15	380	-	4	15	300	7	15	380	4
900-2100	1800	1500	205	255	230	180	15	180	1930	15	225	14	15	300	5	15	360	-	4	15	300	7	15	360	4
2400-3000	1800	1500	205	255	230	180	15	180	1930	15	225	14	15	300	5	15	280	-	4	15	300	7	15	300	4
3300-3900	1800	1500	205	255	230	140	15	140	1930	15	225	14	15	300	5	15	280	-	4	15	300	7	15	300	4
4200-4800	1800	1500	205	255	230	140	15	140	1930	15	225	14	15	300	5	15	280	-	4	15	300	7	15	300	4
5100-6000	1800	1500	205	255	230	210	15	210	1930	15	225	14	15	300	5	15	280	-	4	15	300	7	15	300	4
6300-7500	1800	1500	205	255	230	140	15	140	1930	15	225	14	15	300	5	15	330	-	4	15	300	7	15	330	4

	DIMENSIONS																QUANTITIES				
	k1			m1			k2					m2					CONCRETE m³/m				STEEL
FILL	SIZE	SP	L	SIZE	SP	L	SIZE	SP	L	h	v	SIZE	SP	L	h	v	SLAB	FLOOR	WALLS	TOTAL	kg/m
0	15	182	2160	15	210	2310	15	140	1990	1400	590	15	140	2070	820	1250	0.656	0.701	0.367	1.723	207.1
300	15	182	2160	15	280	2310	15	140	1230	640	590	15	140	2040	790	1250	0.690	0.701	0.367	1.757	182.4
600	20	280	2160	15	140	2310	15	140	1230	640	590	15	140	1840	640	1200	0.543	0.701	0.367	1.610	188.9
900-2100	15	210	2160	15	210	2310	15	140	1150	560	590	15	140	1790	590	1200	0.543	0.701	0.367	1.610	160.5
2400-3000	15	210	2160	15	280	2310	15	140	1130	540	590	15	140	1760	560	1200	0.543	0.701	0.367	1.610	155.3
3300-3900	15	140	2160	15	140	2310	15	140	1130	540	590	15	140	1760	560	1200	0.543	0.701	0.367	1.610	189.8
4200-4800	15	210	2160	15	182	2310	15	140	1130	540	590	15	140	1760	560	1200	0.543	0.701	0.367	1.610	176.4
5100-6000	15	105	2160	20	210	2310	15	105	1230	540	690	15	105	1760	560	1200	0.543	0.701	0.367	1.610	212.0
6300-7500	15	140	2160	20	182	2310	15	182	1280	590	690	15	182	1790	590	1200	0.543	0.701	0.367	1.610	183.3
0	15	182	2160	15	280	2310	15	140	1990	1400	590	15	140	2370	820	1550	0.656	0.701	0.505	1.861	222.7
300	15	182	2160	15	280	2310	15	140	1230	640	590	15	140	2340	790	1550	0.690	0.701	0.505	1.895	202.2
600	15	182	2160	15	140	2310	15	140	1200	610	590	15	140	2140	640	1500	0.543	0.701	0.505	1.748	207.6
900-2100	15	210	2160	15	182	2310	15	182	1150	560	590	15	182	2060	560	1500	0.543	.0.701	0.505	1.748	172.8
2400-3000	15	280	2160	15	182	2310	15	182	1130	540	590	15	182	2060	560	1500	0.543	0.701	0.505	1.748	168.6
3300-3900	15	140	2160	15	140	2310	15	140	1130	540	590	15	140	2040	540	1500	0.543	0.701	0.505	1.748	209.1
4200-4800	15	182	2160	15	182	2310	15	140	1130	540	590	15	140	2040	540	1500	0.543	0.701	0.505	1.748	198.1
5100-6000	15	105	2160	15	140	2310	15	105	1230	540	690	15	105	2040	540	1500	0.543	0.701	0.505	1.748	230.3
6300-7500	20	182	2160	20	182	2310	15	182	1250	560	690	15	182	2090	590	1500	0.543	0.701	0.505	1.748	205.4
0	15	182	2160	15	280	2310	15	140	1990	1400	590	15	140	2680	820	1860	0.656	0.701	0.643	1.999	239.6
300	15	182	2160	15	280	2310	15	140	1280	690	590	15	140	2650	790	1860	0.690	0.701	0.643	2.033	220.2
600	15	182	2160	15	140	2310	15	140	1230	640	590	15	140	2450	640	1810	0.543	0.701	0.643	1.886	225.2
900-2100	15	280	2160	15	280	2310	15	182	1200	610	590	15	182	2420	610	1810	0.543	0.701	0.643	1.886	178.0
2400-3000	15	280	2160	15	140	2310	15	182	1130	540	590	15	182	2370	560	1810	0.543	0.701	0.643	1.886	188.2
3300-3900	15	140	2160	15	140	2310	15	140	1130	540	590	15	140	2370	560	1810	0.543	0.701	0.643	1.886	226.4
4200-4800	15	182	2160	15	182	2310	15	140	1130	540	590	15	140	2370	560	1810	0.543	0.701	0.643	1.886	215.5
5100-6000	15	105	2160	15	140	2310	15	105	1230	540	690	15	105	2370	560	1810	0.543	0.701	0.643	1.886	247.7
6300-7500	20	182	2160	25	210	2310	15	182	1280	590	690	15	182	2400	590	1810	0.543	0.701	0.643	1.886	235.5

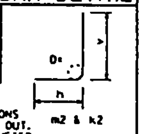
* THESE DIMENSIONS ARE CORRECT FOR 11 480 mm LONG STANDARD SECTIONS ONLY. DIMENSIONS MUST BE RECALCULATED FOR ALL OTHER SECTION LENGTHS.



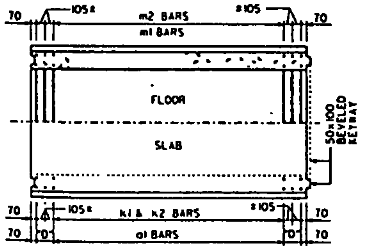
BARREL SECTION

BENT BAR DETAIL

BARS	D
15	100
20	120
25	150
30	240

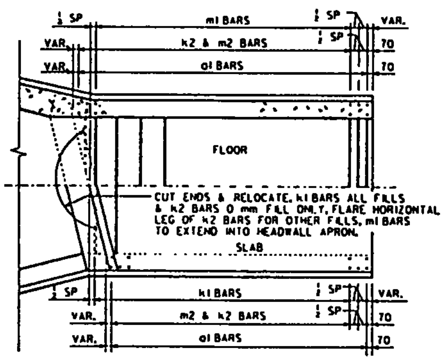


NOTE:
ALL DIMENSIONS ARE OUT TO OUT.
D = PIN DIAMETER.



STANDARD SECTION PLAN VIEW

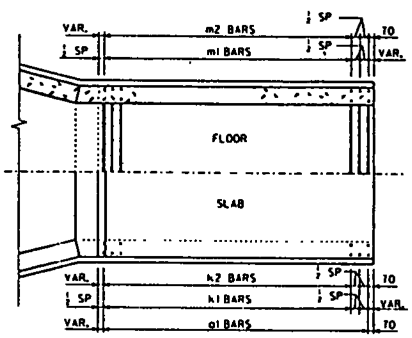
NOTE:
TYPICAL FOR LENGTHS OF 11 480 mm.
(KEYWAY IS TO BE OMITTED WHEN BELL JOINTS ARE USED)



PLAN - SKEW TYPICAL

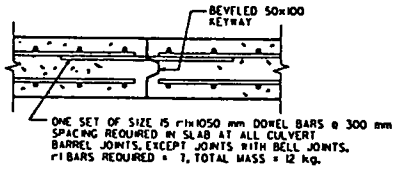
(KEYWAY NOT SHOWN)

NOTE:
ALL LONGITUDINAL BARREL STEEL SHALL EXTEND AT LEAST TO THE BACKFACE OF PARAPET.



PLAN - 0° SKEW

(KEYWAY NOT SHOWN)



TOP SLAB CONSTRUCTION JOINT DETAIL

NOTES:

1. SEE SHEET MRCB-G1-95 FOR GENERAL INFORMATION, SPECIFICATIONS, AND DESIGN STRESSES.

LATEST REVISION DATE:
APPROVED BY:

STANDARD DESIGN

CULVERT BARREL DETAILS

FOR
REINFORCED CONCRETE BOX CULVERTS

PROJECT DEVELOPMENT DIVISION
IOWA DEPARTMENT OF TRANSPORTATION

JULY, 1995

MRCB-1800-1-95

E. The allowable working stress compression for douglas fir, coast type wood piling, parallel to the grain is 1200 psi according to AASHTO. What stress value will be used on the metric plans to obtain this same compression capability?

F. A hooked bar requires that the outer radius of the bend be 4 x bar diameter for the 15M bar. Using the information on the following page:

1. Describe the length of inner and outer radius in terms of mm.

2. The same specification requires 4 bar diameters of length from the end of the 180 degree turn to the short end of the bar. In this case, identify the length of bar represented by this requirement.

CONCRETE REINFORCING STEEL INSTITUTE

CRSI

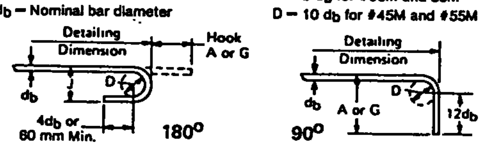
933 N. Plum Grove Road, Schaumburg, IL 60173
Phone: (708) 517-1200

STANDARD METRIC HOOK DETAILS

In accordance with ACI 318M-89

All Grades
D – Finished inside bend diameter
d_b – Nominal bar diameter

D – 6 d_b for #10M through #25M
D – 8 d_b for #30M and 35M
D – 10 d_b for #45M and #55M



RECOMMENDED END HOOKS, ALL GRADES

BAR SIZE	D	180° HOOKS		90° HOOKS
		A or G	J	A or G
#10M	70	140	90	180
#15M	100	180	130	260
#20M	120	220	160	320
#25M	150	280	200	400
#30M	240	400	300	500
#35M	290	460	360	600
#45M	440	660	520	780
#55M	560	860	680	1020

NOTE: All dimensions are in millimeters (mm).

STEEL TYPE	BAR SIZE RANGE	GRADE	MINIMUM YIELD, MPa	MINIMUM TENSILE, MPa
Billet A615M	#10M-#20M #10M-#55M #35M-#55M	300 400 500	300 400 500	500 600 700
Rail A616M	#10M-#35M #10M-#35M	350 400	350 400	550 600
Axle A617M	#10M-#35M #10M-#35M	300 400	300 400	500 600
Low-Alloy A706M	#10M-#55M	400	400	550

OCTOBER 1993

COMBINED ASTM A615/A615M CHART FOR REINFORCING STEEL BARS

Bar Size Designation	Nominal Weight lb./ft.	Nominal Dimensions: Diameter in.	Cross Sectional Area in²
#3	0.376	0.375	0.11
10M	0.527	0.445	0.16
#4	0.668	0.500	0.20
#5	1.043	0.625	0.31
15M	1.055	0.630	0.31
#6	1.502	0.750	0.44
20M	1.582	0.768	0.47
#7	2.044	0.875	0.60
25M	2.637	0.992	0.78
#8	2.670	1.000	0.79
#9	3.400	1.128	1.00
30M	3.692	1.177	1.09
#10	4.303	1.270	1.27
35M	5.275	1.406	1.55
#11	5.313	1.410	1.56
#14	7.65	1.693	2.25
45M	7.91	1.720	2.33
55M	13.19	2.220	3.88
#18	13.60	2.257	4.00

91015M3 CP16A

G. An existing culvert site (as built plans) has identified flow line elevations of 842.50 ft. and 840.00 ft. You have been asked to convert the elevations to metric and lower the inlet 25.4 mm and the outlet 10 mm. What are the design elevations to be placed on the plans?

H. The Iowa DOT Specifications indicate that a prestressed, precast unit may not vary in length ± 6 mm per 8 m or ± 25 mm maximum. A 28.01 m beam is measured at the casting yard. Is this beam acceptable for shipment to the project?

I. Specifications indicate that the Engineer shall compute the mass of the structural steel elements to be incorporated into the structure assuming masses of steel at 7850 kg/m^3 and cast iron at 7210 kg/m^3. Compute the mass of the following rectangular bar stock:

1. Cast Iron bar - 10 mm by 5 mm by 30 m

2. Steel bar - 22 mm by 0.10 m by 25.50 m

J. A bridge deck is to be built as part of a superelevated curve. The centerline elevation at Station 25+65.00, in full superelevation is 474.25 m. Assuming an 8% superlevation rate, what will the elevation be at each gutter line 5600 mm from centerline?

K. A wood deck is to be placed on a residential drive access bridge. It will consist of a double layer of 0.075 m thick wood planking. Specifications indicate a need for nails that are not less than 2.5 times the nominal thickness of the decking. What length mm nails will you specify for use in this work?

L. Concrete bridge floors are to be placed only when the temperature is below 32°C. The contractor has misplaced the Celsius thermometer and the Fahrenheit thermometer indicates a temperature of 95°F. Should you allow the concrete to be placed in the bridge floor?

M. Bridge decks are to be covered with curing compound at the rate of not more than 3.3 m^2/L. It the deck dimensions are 55.40 m by 13.50 m, what is the maximum volume of curing compound that is acceptable for use?

N. A two slab bridge, 40 m in length by 13.5 m width, is to be built on a +2% longitudinal grade with a cross slope of 2% from centerline. If the finish elevation of the center cap is 248.60 m and the depth of deck is 250 mm, what will the elevations of be at each gutter line at the four corners of the deck?

O. A roadway crosssection consisting of a 13 m width, 3:1 foreslopes and a centerline grade elevation of 848.50 m at Sta 49+00 is the location for a culvert. The 2700 mm diameter culvert is to be placed with an invert elevation of 838.00 m and an outlet elevation of 837.50 m. What is the length of the culvert in meters?

P. Specifications indicate that multiple pipe culvert structures must be spaced at 50% of the pipe diameter and not more than 1 m apart. Two 1200 mm diameter pipes are being placed. What spacing will be specified?

Q. The bearing capacity for gravity hammers of a piling (wood, steel H or shell pile) where the wave equation is not required is computed by the formula:

$P = [2.5WH/(S+8.9)][W/(W+M)]$

where P = The bearing value in kilonewtons

W = The mass of the gravity hammer, or the ram of the air hammer or diesel hammer in kilograms

H = The height of free fall or the hammer or ram in meters

M = The mass in kilograms of the pile plus the mass in kilograms of the cap plus (for diesel hammers) the mass of the anvil in kilograms.

S = The average penetration in millimeters of the pile per blow for the last 5 blows for gravity hammers and the last 10 blows for air or diesel hammers.

Assuming the mass of the hammer is 2500 kg, the height of free fall is 600 mm, mass of pile and cap is 1200 kg, and the average penetration per blow is 0.022 m. What is the bearing capacity of the piling?

Record Keeping

Unit 4

Unit 4 - SI Applications in Record Keeping

This part of the workshop will introduce you to the basic reading and writing rules of SI Metric and some of the standard conventions used in the Iowa DOT. Following these few simple rules will make it easier for us to understand each other, and lessen the chance for errors or misinterpretation. Topics covered will include:

- Proper notation
- Prefixes
- Spacing
- Capitalization
- Spelling
- Singular/Plurals
- Decimal markers
- Powers of ten
- Separating digits
- Intended Precision
- Rounding
- Estimating

At the end of this unit you will have the opportunity to complete a worksheet which will help you demonstrate your grasp of the metric concepts covered in this part of the workshop.

The following pages contain an outline/guide which was extracted from a video entitled SI Metric: Reading, Writing, Rules. Although you will not be viewing this video as part of this workshop, the information in the outline may be helpful to you in the future.

Reading, Writing, Rules Video Outline

Reasons for correct usage

avoid mistakes

eliminate need for translation

SI Symbols

most are lower case

exceptions - when the symbol is derived from a proper name

no periods - these are not abbreviations!

no plurals or "s" on symbols

unit names	symbols
meter	m
kilogram	kg
newton	N
pascal	Pa
square meter	m^2
cubic meter	m^3
liter	L
degree Celsius	°C

Prefixes

no space between prefix and unit

no hyphen between prefix and unit

all prefixes below 1,000,000 (mega) have lower case symbols
all prefixes from mega and above the prefixes are uppercase symbols

never mix with abbreviations

examples:

name	symbol
kilogram	kg
meganewton	MN
kilopascal	kPa

Prefixes continued:

only one prefix allowed

No -- kMN or Mmm

Spelling, Capitalizing, and Plurals

Unit names when written out are all lower case... even those derived from proper names such as pascal and newton. The only exception is degree Celsius

In the U.S. use meter and liter (not metre and litre)

Plural may use an optional "s" don't need it

kilogram or kilograms

between the prefix and the unit:
no separation (not milli meter)
no hyphens (not milli-meter)

millimeter is correct

degree Celsius or degrees Celsius

For area or volumes.... square and cubic are written first in name, but shown as an exponent in symbol

name	symbol
square meter	m^2
cubic meter	m^3

(Not meters square)

Spacing

leave a space between the numerical value and the SI unit symbol

Examples:

35 mm

7.63 kPa

NOTE: The video is wrong when it discusses degrees Celsius. There is NOT a space between the numeric value and the degree symbol.

Example:

Wrong ---- 37 °C
Correct --- 37°C

Obsolete Metric

Old	Correct SI
10K	10 km
K	kg
KPH	km/h
kilos	kilograms
grm or gm	g
Newton	newton
cc, ccm	cm^3

Decimal Points, Commas, and Groups of Three

if number is a decimal less than 1, use a leading "0" (Example: 0.1234)

outside of the U.S. many people use a comma instead of a period to indicate the decimal point. this can be confusing

1.33 US = 1,33 Outside US

rather than grouping every three numbers with a comma, as we do in the US, SI uses a small space

old US English system	1,365,020.034589
SI system (using decimal point)	1 365 020.034 589

group all numbers in three except when it is only a four digit number

Correct:	4567.987
Incorrect:	4 567.987

NOTE: The Iowa DOT will continue to use the standard English system method of grouping. The period will still be used for the decimal point, and commas will be used to separate every three digits.

Powers of Ten

sometimes people prefer to represent values as powers of ten of the base unit rather than using the prefixes

Examples:

power of 10 representation	equivalent SI prefix
123.4×10^{-3} m	123.4 mm
12.34×10^{6} N	12.34 MN
1.234×10^{3} Pa	1.234 kPa

Unit 4 - SI Applications in Record Keeping

Intended Precision

"Wat does the number really reflect, and how will it be used"

Example of a quart of oil
1 qt = 0.9463529 L
however, when you add oil to your car... would substitute 1L for 1 qt
(you are not going to measure to 0.0000001 L to get 0.9463529L)

All conversions must reflect an intended precision of the original quantity which can be implied by significant digits (and/or tolerance)

Examples:

1.54 quarts has 3 significant digits
intended precision is +/- one-half of the last significant digit
1.54 ..... +/- 0.005
1.535 ... 1.54 ... 1.545 (true measurement somewhere between 1.535 and 1.545)

given number	probable intended precision	range number between
5.14	+/- 0.005	5.135 ... 5.145
645.117	+/- 0.0005	645.1165 ... 645.1175
10.	+/- 0.5	9.5 ... 10.5
10	+/- 1	9 ... 11

Be cautious with decimals... could represent fractions and mislead you on the number of significant digits. For example: 3.1875 could mean 3.1875 or 3-3/16. Would have different "intended precision" with these two.

Be cautious of numbers with no decimal places... "5" could mean approximately 5 or could mean 5.0000

Knowledge of the circumstances related to the measurement are important
understand accuracy of measuring equipment
origination of the measurement
purpose of the original measurement
purpose of the conversion
(all of the above give you information about the intended precision)

Rounding Rules

If number after last significant digit to be saved is less than 5, drop the numbers

4.763534 round to 2 after decimal place = 4.76
234.8732 round to 3 after the decimal place = 234.873
87632 round to nearest hundred = 87600

If the number after last significant digit to be saved is greater than 5, add one to last number

4.763534 round to 1 after the decimal place = 4.8
234.8732 round to 1 after the decimal place = 234.9
87632 round to nearest thousand = 88000

Rounding Rules (continued)

If the number after the last significant digit to be saved is exactly equal to 5 (with nothing after it) then

... Make the number an even number.....

If the last significant digit is odd... round up
If the last significant digit is even... do nothing (drop 5)

476.55 round to 1 after decimal = 476.6
445.25 round to 1 after decimal = 445.2

Importance of Estimating

When doing conversion calculations, it is easy to hit the wrong key on the calculator therefore it is important to do two things:

1) double check the answer (punch the numbers again) to see if you get the same answer
2) verify your answer using estimations and common sense

For example if you are converting 25 miles per hour to kilometers per hour....

Your answer should be 25 x 1.609 = 40.225 km/h => 40 km/h

However if you typed 16.09 instead of 1.609 your answer would say 402.25 or 402 km/h

When you get your answer stop and think... use your visualizing metric rules of thumb, does the answer seem logical???

We know that a kilometer is a little more than half a mile (about .6). Therefore in the same amount of time (one hour) we would expect to go almost twice as many kilometers as miles (or 50). An answer of 402 is obviously not the correct. The correct answer of 40 is reasonable.

The more familiar you become with SI metric units, the easier it will be for you to recognize when you have made a mathematical error. Until then... double check your work!

Unit 4 - SI Applications in Record Keeping

Worksheet Review

1. What is the correct symbol for megapascals?

   A. Mpa
   B. MPa
   C. mPa
   D. mPA

2. What is the correct symbol for cubic millimeter?

   A. cu. mm.
   B. mm^3
   C. cmm
   D. mm ^{3}

3. Which of the following is not a correct SI plural?

   A. 44.65 m
   B. 5.4 kilopascal
   C. Eighteen cubic millimeters
   D. 149 MNs

4. Which of the following is the correct representation of temperature in degree Celsius?

   A. 42.5°c
   B. 42.5 °C
   C. 42.5 °c
   D. 42.5°C

5. Which of the following is correct?

   A. $19mm^3$
   B. 448 cmm
   C. 18 Mn
   D. 55.7 kPa

6. Which of these expressions is a proper expression for kilometers per hour?

   A. 75 KPH
   B. 75 Km/H
   C. 75 km/h
   D. 75 km/hr

7. Which of the following expressions is equivalent to 1×10^4 square millimeters?

   A. 10 000 mm^2
   B. 1000 mm^2
   C. 0.0001 mm^2
   D. 0.001 mm^2

Worksheet Review

8. Which of the following pairs of symbols and unit names is correct?

A.	17 MPa	17 Megapascals.
B.	3434.6 N	3434.6 Newtons
C.	1.67 kg	1.67 kilograms
D.	2.3 mm	2.3 milli-meters

9. Which of the following is a correct sentence for temperature?

A. The temperature outside was ten Degrees Celsius.
B. The temperature outside was ten degrees celsius.
C. The temperature outside was ten degrees Celsius.
D. The temperature outside was ten Degrees celsius.

10. Which of the following is correct?

A. .78 kg/m^2
B. 3.9 L's
C. 4.539 KPa
D. 3.87 ha

11. Round the following numbers as specified

	Round to
a) 34.876	2 after decimal place
b) 87.565	2 after decimal place
c) 1234	10's place
d) 876.52	whole number
e) 0.2347	3 after decimal place

SI Tables

SI Metric Tables

SI Base Units

Quantity	Name	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

SI Supplementary Units

Quantity	Name	Symbol
plane angle	radian	rad
solid angle	steradian	sr

SI Derived Units with Special Names

Quantity	Name	Symbol	In terms of Other Units
frequency	hertz	Hz	s^{-1}
force	newton	N	$kg \cdot m \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2
energy, work	joule	J	N·m
power	watt	W	J/s
electric charge	coulomb	C	s·A
electric potential	volt	V	W/A
capacitance	farad	F	C/V
electric resistance	ohm	Ω	V/A
electrical conductance	siemens	S	A/V
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb/m^2
inductance	henry	H	Wb/A
luminous flux	lumen	lm	cd·sr
illuminance	lux	lx	lm/m^2
activity (radio)	becquerel	Bq	s^{-1}
absorbed dose	gray	Gy	J/kg
dose equivalent	sievert	Sv	J/kg

SI Metric Tables

Acceptable Units to Use with SI Units

Quantity	Name	Symbol	In terms of Base Units
temperature	degree Celsius	^oC	K (t^oC=t K - 273.15)
volume	liter	L	10^{-3} m^3
mass	tonne (metric ton)	t	10^3 kg
time	minute	min	60 s
time	hour	h	3600 s
time	day	d	86 400 s
angle	degree	^{o}	(π/180) rad
angle	minute	'	(π/10800) rad
angle	second	"	(π/648000) rad
area	hectare	ha	100m x 100m or 10^4 m^2

Commonly Used Prefixes

Multiple of 10	Prefix	Symbol
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n

Additional Prefixes

Multiple of 10	Prefix	Symbol
10^{24}	yotto	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^2	hecto	h
10^1	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

SI Metric Tables

Conversion Factors: English to SI Metric

Quantity	From English Unit:	To SI Metric Unit:	Multiply by:
length	mile	km	1.609347
	yard	m	0.9144
	foot	m	0.3048006 (See note)
	inch	mm	25.4
area	square mile	km^2	2.5989998
	acre	m^2	4047
	acre	hectare	0.4046873
	square yard	m^2	0.8361274
	square foot	m^2	0.09290304
	square inch	mm^2	645.16
volume	acre foot	m^3	1233
	cubic yard	m^3	0.7645549
	cubic foot	m^3	0.02831685
	cubic foot	L	28.32
	100 board feet	m^3	0.2360
	gallon	L	3.785412
	cubic inch	cm^3	16.39
	cubic inch	mm^3	16387.06
	fluid ounce	milliliter	29.57353
mass	lb	kg	0.4535924
	kip (1000 lb)	metric ton	0.4536
	ton (2000 lb)	megagram	0.9071847
	ounce	gram	28.34952
force	lb	N	4.448
	kip	kN	4.448
pressure, stress	pound per sq. ft (psf)	Pa	47.88
	pound per sq. inch (psi)	kPa	6.895
bending moment or torque	ft-lb	N·m	1.356
density	lb per cubic yard	kg/m^3	0.5933
	lb per cubic foot	kg/m^3	16.02
velocity	ft/s	m/s	0.3048
	mph	m/s	0.4470
	mph	km/h	1.609
power	ton (refridg)	kW	3.517
	BTU/h	W	0.2931
	hp (electric)	W	745.7
volume flow rate	cubic ft per sec.	m^3/s	0.02832
	cfm	m^3/s	0.0004719
	cfm	L/s	0.4719
angles	degree	radian	0.01745329
temperature	°F	°C	(t°F-32)/1.8

Note: 39.37 inch = 1 m (For US Survey foot, 12 inches per foot)

Reference

References

1. STANDARD SPECIFICATIONS FOR HIGHWAY BRIDGES, Fifteenth Edition, AASHTO, 1992.

2. A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS, AASHTO, 1994.

3. T.J.Wipf, F.W.Klaiber, H.El-Arabaty, METRIC SHORT COURSE FOR THE OFFICE OF BRIDGES AND STRUCTURES, IHRB HR-378, February 1995.

4. METRIC STANDARD SPECIFICATIONS FOR HIGHWAY AND BRIDGE CONSTRUCTION, Series 1995, Iowa Department of Transportation.

5. IOWA DEPARTMENT OF TRANSPORTATION POLICIES AND PROCEDURES MANUAL, Metric Style, Policy 030.02, 1994.

Answers

Metric Training for the Transportation Industry
Module 3 - Road & Bridge Design Answers

Unit 1

1. A - liter
2. D - Degree Celsius
3. B - Pound force
4. A - meter and C millimeter
5. C - 0°C
6. B - cubic meter
7. C - 0.2 km
8. B - 3000 mm
9. C - 0.05 km
10. B - Metric system used today
11. C - 3.4 N
12. C - Pa

Unit 2

A. Minimum radius value

R(m) = (V km/h)^2/[127 x (e+f)]

1. = 80^2/[127x(0.08+0.11)] = 265.23 m
2. = 100^2/[127x(0.08+0.11)] = 414.42 m
3. = 110^2/[127x(0.08+0.11)] = 501.45 m

B. Spiral Curve length to nearest 5 m

Lm = 0.0702 V^3/RC (C = 1, R radius in m)

Lm = 0.0702 x 110^3 /(501.45)(1)

= 186.33 m ~ 190 m

(round up)

Unit 2

C. Curve Lm, Tm, Em lengths

Lm = 3.1416 (R) x delta/180

= 3.1416 (501.45) x 6/180 = 52.51 m

Tm = R(Tan (delta/2))

= 501.45(Tan(3°))

= 501.45(0.05241) = 26.28 m

Em = R[1/cos(delta/2)-1]

= 501.45[1/cos(3°) -1]

= 501.45[(1/0.99863)-1] = 0.69 m

Unit 2

D. Stopping sight distance

d_1 = 0.278 t_1 V   assume t_1 = 2.5 s

= 0.278 (2.5)(100) = 69.5 m

d_2 = V^2/[254(f±g)]

=100^2 /254(0.28-0.03) = 157.5 m

Total distance = 227.0 m

Unit 2

E. Passing sight distance

d_1 = 0.278 t_1(V-m+at_1/2)

= 0.278(4)(80-5+1(4/2))

= 77.22 m

d_2 = 0.278 t_2(V)

= 0.278 (10)(80) = 222.40 m

d_3 = assume 55 m

d_4 = 2/3(d_3) = 2/3(55) =36.67 m

Total = 391.91 m ~ 395 m

<u>Assume:</u>

t_1 =3-4.5 s

m = 5 km/h

a = 1 m/s^2

t_2 = 9.3-11.3 s

V =80 km/h

Unit 2

F. Superelevation transition length

Lm = 2.72 f V/C   assume C=1

= 2.72(0.4)(100)/1 = 108.8 m ~ 110 m

Metric Training for the Transportation Industry
Module 3 - Road & Bridge Design Answers

Unit 2

G. Desirable curve length difference between 100 and 110 km/h

Given $g_1 = 2\%$ $g_2 = -2.5\%$ $V_1 = 100$ km/h

$V_2 = 110$ km/h

$A = [(g_2-g_1]= [-2.5-2] = 4.5\%$

$S_{100} = 205.0$ m $S_{110} = 246.4$ m

$K_{100} = 105$ m/%A $K_{110} = 151$ m/%A

L = KA =105(4.5) L = KA = 151(4.5)

= 472.5 m = 697.5 m

Assume S<L $L = AS^2/404$

$S100 = \sqrt{472.5(404)/4.5}$ $S110 = \sqrt{697.5(404)/4.5}$

= 205.96 m ok = 250.23 m ok

Difference = 697.5 - 472.5 = 225.0 m

Unit 2

H. Minimum curve length

Lm = 0.6 Vm =0.6(100) = 60 m

I. Length of curve in "G" for V=110 km/h to allow passing sight distance?

Assume S<L $L= AS^2/946$

$L = 4.5(728)^2/946 = 2521.07$ m

Unit 2

J. Desirable length of curve

A = [0.5-(-2.8)] = 3.3

assume S<L

$L= AS^2/(120+3.5S)$

$= 3.3(168.7)^2 / (120+3.5(168.7))$

= 93916.977 / 710.45 = 132.19 m ~ 132 m

$K_{90} = 40$ m/K

L=KA=40(3.3) = 132

Use 135 m

Unit 2

K. Minimum length of sag curve in "J"

$Lm = AV^2/395 = 3.3(90)^2/395$

= 67.67 m

L. Drainage area in hectares

1 mi^2 x 640 ac/mi^2 x0.4047 ha/ac = 259.01 ha

M. Bridge Clearance (nearest 0.1 m)

14.5 ft x 0.3048 m/ft = 4.4196 m ~ 4.4 m

Unit 2

N. Pavement and shoulder widths

Pavement 22 ft x 0.3048 m/ft = 6.7 m

Shoulder 8 ft x 0.3048 m/ft = 2.4 m

O. No particular answer

P. Station Conversion

1. $67550.25 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{1 \text{ m}}{39.37 \text{ in}} = 205+89.36$ m

2. 675+50.25 (E) = 205+89.36 (m)

Unit 2

Q. Lengths of Div I and II

Div I	2269.50	Div II	2350.00
	-243.84		-2269.50
	2025.66		80.50

1. Total = 2025.66+80.50 = 2106.16 m

2. Revised EOP Sta. Div II

1.5 mi x 1.609 km/mi = 2.4135 km

Sta 2350.00+2413.50 = 4763.50

=47+63.50 (m)

Metric Training for the Transportation Industry
Module 3 - Road & Bridge Design Answers

Unit 2

Q. Continued

3. Granular surfacing plate 2108
volume => 101607.63 - 101530.00 = 77.63 m
77.63 m x 0.155 m x 6 m = 72.20 m^3

mass => 4100 kg/m^3 x 72.20 m^3 = 296,020 kg
= 296.02 Mg

4. Granular subbase plate 2211
2269.50
- 243.84
2025.66 m

Unit 2

Q. Continued

5. Volume of special backfill plate 2209
2350.00 - 2269.50 = 80.50 m
80.50 m x 0.3 m x 5.7 m x 2 = 275.31 m^3

6. Area of concrete plate 2201
102900.00
-101618.33
1281.67 m x 7.2 m = 9228.02 m^2

7. See quantity sheet

Unit 2

Q. Continued

8. Seed quantities (May 21 - July 20)
Oats 15.6 ha x 108 kg/ha = 1684.8 kg
Rye 15.6 ha x 39 kg/ha = 608.4 kg
Clover 15.6 ha x 6 kg/ha = 93.6 kg
Timothy 15.6 ha x 6 kg/ha = 93.6 kg

9. Length of type 1601, 750 mm pipe = 25.0 m

10. Volume of class 10 and unsuitable
Class 10 == 6819 m^3
Unsuitable == 1921 m^3

Unit 2

Q. Continued

11. Special ditch elevations

Sta 5+00 elev = 443.10 m
Sta 6+00 elev = 441.10 m

Unit 3

A. Bridge length

2 @ 30'6" => 30 ft x 12 in/ft+6= 366 in
2 x (366 in x 25.4 mm/in) = 18592.8 mm

1@ 39'0" => 39 ft x 12 in/ft x 25.4 mm/in
= 11887.2 mm
total = 30480.0 mm

B. Concrete strength
4000 psi x 6.895 kPa/psi = 27580 kPa
= 27.58 MPa
Rounded to 30 MPa overstates by +9%

Unit 3

C. Rebar
4%/m^2 = 0.04 x 1000 x 1000 = 400 mm^2
1. #10M 400/100 = 4/m^2
2. #30M 400/700 = 1/m^2

D. Culvert Quantities
1. Concrete volume
1.610 m^3/m x 20 m = 32.2 m^3
2. Steel mass
176.4 kg/m x 20 m = 3528 kg
3. Steel mass change
183.3 kg/m x 20 m = 3666 kg
3666 kg - 3528 kg = 138 kg

Metric Training for the Transportation Industry
Module 3 - Road & Bridge Design Answers

Unit 3

E. Formwork stress

1200 psi x 6.895 kPa/psi = 8274 kPa
= 8.27 MPa

F. Rebar dimensions

1. Outer R
   4 x 0.63 in x 25.4 mm/in = 64.01 mm
   Inner R
   64.01 mm - (0.63 in x 25.4 mm/in)
   = 48.00 mm

2. Bar length
   4 x 0.63 in x 25.4 mm/in = 64 mm

Unit 3

G. Culvert inlet and outlet elevations

Inlet
[(842 ft x 12 in/ft)+ 6 in] (25.4 mm/in) - 25.4 mm
= 256770 mm = 256.77 m

Outlet
(840 ft x 12 in/ft) (25.4 mm/in) -10.0 mm
= 256020 mm = 256.02 m

Unit 3

H. Beam Acceptability

28.01 m /8 m = 3.5 segments

3.5 x 0.006 = 0.021 m

28.01 < 28.021 beam is okay
21 mm < 25 mm

Unit 3

I. Bar mass

1. Cast Iron
   0.010 m x 0.005 m x 30 m x 7210 kg/m³
   = 10.82 kg

2. Steel
   0.022 m x 0.10 m x 25.5 m x 7850 kg/m³
   = 440.38 kg

Unit 3

J. Gutter Elevation

0.08 x 5.60 m = 0.448 m ~ 0.45 m
Elev = 474.25 - 0.45 = 473.80 m
Elev = 474.25 + 0.45 = 474.70 m

K. Nail length

2 x 2.5 x 75 mm = 375 mm

L. Concrete temperature

(95°F-32)/1.8 = 35°C > 32°C no, reject

M. Curing compound amount

55.40 m x 13.5 m /3.3 m²/L = 226.64 L

Unit 3

N. Gutter elevations

Top of slab centerline elevation
248.60 m + 0.250 m = 248.85 m
Centerline elevations at each end
248.85 m + 20 m (0.02) = 249.25 m
248.85 m - 20 m (0.02) = 248.45 m
Gutter elevations
249.25 m - 6.75 m (0.02) = 249.11 m
248.45 m - 675 m (0.02) = 248.31 m

Unit 3

O. Pipe length

L = 13 + (848.5-838.0)(3) + (848.5-837.5)(3)
= 13 + 10.5(3) + 11(3)
= 77. 5 m

P. Pipe spacing

1.2 m x 0.5 = 0.60 m
0.60 m < 1 m   use 0.6 m spacing

Unit 3

Q. Pile Bearing

P = [2.5WH/(S+8.9)][W/(W+M)]
= [2.5 (2500)(0.6)/(22+8.9)][2500/(2500+1200)]
= 121.359(0.67567)
= 81.9986 kN
~ 82 kN

Unit 4

1) B
2) B
3) D
4) D
5) D
6) C
7) A
8) C
9) C
10) D

11 a) 34.88
b) 87.56
c) 1230
d) 877
e) 0.235

Introduction to SI Metric
Module 3

Created by:

Karen Zunkel &
Jim Cable
Iowa State University

Workshop Overview

- ✦ Unit 1 - History and SI Basics
- ✦ Unit 2 - SI Applications in Road Design
- ✦ Unit 3 - SI Applications in Bridge Design
- ✦ Unit 4 - Record Keeping

Why Use SI Metric?

- To join the global marketplace (only 3 countries don't use SI metric)
- We already use many SI units
- International communication
- International competitiveness
- Simplicity / Efficiency
- Sept. 30, 2000 - all highway/lands receiving federal aid must be bid, designed, & constructed using SI

SI Basics

Topics Covered

- ✦ Seven base units of SI
- ✦ Derived units
- ✦ Supplemental units
- ✦ Prefixes
- ✦ Additional units to use with SI

SI Base Units

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

Mass versus Weight

We are familiar with "weight"

We say... "I weigh 130 pounds"

Pounds are actually units of force (lb_f)

Force = mass x acceleration of gravity

Acceleration due to gravity varies

Easiest diet ... move to the moon! Even though I have the same body, I weigh less (about 1/5 as much).

Mass versus Weight (cont.)

English

$lb_f = lb_m \times 32.2$ (where 32.2 ft/s^2 is common acceleration of gravity)

SI Metric

newtons = kilograms x 9.806

(where 9.806 m/s^2 is common acceleration of gravity)

Mass versus Weight (cont.)

To ease the "transition"... conversion tables will list "from pounds force" to "kilograms"

$$1\ lb_f = 0.4536\ kg$$

(force) to (mass)

This conversion uses the standard acceleration of gravity on earth to translate a force back to a mass.

SI Supplementary Units

Quantity	Name	Symbol
plane angle	radian	rad
solid angle	steradian	sr

Note: Iowa DOT will continue to use degrees for surveying. However, other angular measurements will likely be in radians.

SI Derived Units

- A combination of base units and prefixes
- Example: meters per second = m/s
- Some derived units have special names (Ex: newtons => force)
- See table in handout for a listing

Other Acceptable Units

Quantity	Name	Symbol
temperature	degree Celsius	°C
volume	liter	L
mass	tonne(metric ton)	t
angle	degree	°
angle	minute	‘
angle	second	“

Other Acceptable Units

Quantity	Name	Symbol
time	minute	min
time	hour	h
time	day	d
area	hectare	ha

Note: hectare is shortened from square hectometer . Hecto is prefix for 100... so a hectare is 100 m by 100 m

Common Prefixes

Prefix	Symbol	Power of 10
giga	G	10^9
mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

Prefix Example Conversions

1000 mm = 1 m

1000 m = 1 km   So for example....

$$1\text{ km} \times \frac{1000\text{ m}}{1\text{ km}} \times \frac{1000\text{ mm}}{1\text{ m}} = 1{,}000{,}000\text{ mm}$$

Ex. 1) $250\text{ mm} \times \frac{1\text{ m}}{1000\text{ mm}} = 0.250\text{ m}$

Ex. 2) $35\text{ km} \times \frac{1000\text{ m}}{1\text{ km}} = 35{,}000\text{ m}$

Visualizing Metric

Sample answers

- ✦ Height: 5’6” = 1676 mm = 1.676 m
- ✦ Pace: 53 cm = 530 mm = 0.53 m

Worksheet Answers

1) Which of the following expresses fluid volume?

A. liter

B. cubic kilogram

C. pascal

D. hectare

Worksheet Answers

2) Which unit of temperature is used at construction sites?

A. degree Fahrenheit

B. degree Centigrade

C. kelvin

D. degree Celsius

Worksheet Answers

3) Newton replaces which unit?

A. pounds per square inch

B. pound force

C. pounds per cubic inch

D. pounds mass

Worksheet Answers

4) Iowa DOT drawings will use which measurements? (circle all that apply)

A. meter

B. centimeter

C. millimeter

D. megameter

Worksheet Answers

5) On the Celsius scale, water freezes at what temperature?

A. 32^{o}C

B. 100^{o}C

C. 0^{o}C

D. 0 K

Worksheet Answers

6) Which SI Unit listed here would be used to express volume of concrete or fill?

A. cubic decimeter

B. cubic meter

C. liter

D. ton

Worksheet Answers

7) Which of the following is the same as 200 meters?

A. 0.02 km

B. 2.0 km

C. 0.2 km

D. 20.0 km

Worksheet Answers

8) Which of the following is the same as 3 meters?

A. 0.03 km

B. 3000 mm

C. 300 mm

D. 0.3 km

Worksheet Answers

9) Which of the following represents the longest length?

A. 3.0 m	3.0 m
B. 450 mm	0.45 m
C. 0.05 km	50 m
D. 20 cm	0.2 m

Worksheet Answers

10) SI refers to:

A. The system of interfaces necessary to implement metric in computers.

B. The metric system used today.

C. The governing organization that establishes metric rules.

D. The international strategies that created first metric system.

Worksheet Answers

11) On the moon the acceleration of gravity is about 1.7 m/s^2. What is the gravity force of a 2 kg object on the moon?

A. 3.4 pascals

B. 1.7 pascals

C. 3.4 newtons

D. 1.7 newtons

Worksheet Answers

12) Which SI unit replaces PSI?

A. kg/m^2

B. N

C. Pa

D. newton-meters

Unit 2 - Road Design Topics

Topics Covered

- ✦ Conversion Types and Factors
- ✦ Road Design Problems

Soft Conversion

- ✦ Use factors on English units to get metric equivalent - 1 step
- ✦ Often will lead to long, “strange” numbers
- ✦ Going “soft” on us... use new measurement system, but don’t change physical value
- ✦ Example: 16.0 ft == 4.88 m

Hard Conversion

- ✦ Use factors on English units to get metric equivalent ... then round to "reasonable" metric number - 2 steps
- ✦ Going "hard" or tough on us... use new measurement system, and probably even change physical value
- ✦ Example: 16.0 ft == 5.0 m

Hard Conversion

Pipe diameter 30" == 762 mm

hard conversion == 750 mm

Lane width 12' == 3.6576 m

hard conversion == 3.6 m

Pavement thickness 10" == 254 mm

hard conversion == 260 mm

Long Form

Feet to Meters

	0	.1	.2	.3
0	0	0.03048	0.06096	0.09144
1	0.30480	0.33528	0.36576	0.39624
2	0.60960	0.64008	0.67256	0.70104
3	0.91440	0.94488	0.97536	.....

Example: 2.2 feet equals 0.67256 meters

Short Form

Length

	m	in	ft	yd
m	1	39.370	3.2808	1.0936
in	25.4×10^{-3}	1	83.333×10^{-3}	27.0778×10^{-3}
ft	0.3048	12	1	0.3333
yd	0.9144	36	3	1

Example: 1 foot = 0.3048 meters

2ft x 0.3048 = 0.6096 m

Conversion Factors

Quantity	From	To	Multiply by
Length	ft	m	0.3048
	in	m	25.4×10^{-3}
	yd	m	0.9144
Mass	lbm	kg	0.4536

Example: 2ft x 0.3048 = 0.6096 m

Rounding Rules

Less than 5 - Drop the numbers

Number	Place	Rounded
4.763534	2 after decimal	4.76
234.8732	3 after decimal	234.873
87632	hundreds	87600

Rounding Rules (cont)

Greater than 5 - Raise (Add 1 to) the number

Number	Place	Rounded
4.763534	1 after decimal	4.8
234.8732	1 after decimal	234.9
87632	thousands	88000

Rounding Rules (cont)

Exactly equal to 5 (With nothing after it!)

- Make the number even

If last significant digit is odd... round up

If last significant digit is even.. drop number

Number	Place	Rounded
476.55	1 after decimal	476.6
445.25	1 after decimal	445.2

Rounding Rules - standards

DOT establishing standards for "rounding"/precision for many items

Examples:

- ✦ Reinforced concrete boxes - to tenth of a meter (1.8 x 1.2 x 9.8)
- ✦ Horizontal alignments, tie-ins, etc. - to closest 0.001m (tolerances ± 3mm)

Rounding Rules - standards

More examples:

- ✦ **Entrance locations - closest 0.01 m**
- ✦ **Culvert locations - closest 0.1 m**

(Note: many other standards, such as scales on plans, etc... see DOT metric conversion guidelines and AASHTO green book. etc...)

Verifying Answers

- ✦ Humans aren't perfect
- ✦ Double check your answers
- ✦ Use common sense and estimates

Verifying Answers (cont.)

Example: Convert 25 mph to km/h

Correct Answer: 25x1.609 = 40.225

40 km/h

What if you mistyped 1.609 as 16.09 on your calculator??? 25x16.09 = 402.25

402 km/h

Station Conversion

$$492{+}00.00 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{1 \text{ m}}{39.37 \text{ in}} = 149{+}96.190 \text{ m}$$

Station Equation

Sta 149+96.190 (m) This survey/sta 492+00.0(E) as built

OR

Sta 149+96.19 (m) = Sta 492+00.0 (E)

US Foot Conversion

$$\frac{39.37\text{ in}}{1\text{ m}} \times \frac{1\text{ ft}}{12\text{ in}} = \frac{39.37\text{ ft}}{12\text{ m}} = 3.28083\text{ ft/m}$$

Unit 2

A. Minimum radius value

$R(m) = (V\ km/h)^2/[127 \times (e+f)]$

1. $= 80^2/[127x(0.08+0.11)] = 265.23$ m
2. $= 100^2/[127x(0.08+0.11)] = 414.42$ m
3. $= 110^2/[127x(0.08+0.11)] = 501.45$ m

B. Spiral Curve length to nearest 5 m

$Lm = 0.0702\ V^3/RC$ (C = 1, R radius in m)

$Lm = 0.0702 \times 110^3 /(501.45)(1)$

$= 186.33$ m ~ 190 m (round up)

Unit 2

C. Curve Lm, Tm, Em lengths

Lm = 3.1416 (R) x delta/180

= 3.1416 (501.45) x 6/180 = 52.51 m

Tm = R(Tan (delta/2))

= 501.45(Tan(3°))

= 501.45(0.05241) = 26.28 m

Em = R[1/cos(delta/2)-1]

= 501.45[1/cos(3°) -1]

= 501.45[(1/0.99863)-1] = 0.69 m

D. Stopping sight distance

$d_1 = 0.278\ t_1\ V$ assume $t_1 = 2.5$ s

$= 0.278\ (2.5)(100) = 69.5$ m

$d_2 = V^2/[254(f \pm g)]$

$= 100^2/254(0.28-0.03) = 157.5$ m

Total distance = 227.0 m

Unit 2

E. Passing sight distance

$d_1 = 0.278\ t_1(V\text{-}m+at_1/2)$

$= 0.278(4)(80\text{-}5+1(4/2))$

$= 77.22$ m

$d_2 = 0.278\ t_2(V)$

$= 0.278\ (10)(80) = 222.40$ m

d_3 = assume 55 m

$d_4 = 2/3(d_3) = 2/3(55) = 36.67$ m

Total = 391.91 m ~ 395 m

<u>Assume:</u>

t_1 =3-4.5 s

m = 5 km/h

$a = 1\ m/s^2$

V =80 km/h

t_2 = 9.3-11.3 s

Unit 2

F. Superelevation transition length

$Lm = 2.72 f V/C$ assume $C=1$

$= 2.72(0.4)(100)/1 = 108.8 \text{ m} \sim 110 \text{ m}$

Unit 2

G. Desirable curve length difference between 100 and 110 km/h

Given $g_1 = 2\%$ $g_2 = -2.5\%$ $V_1 = 100$ km/h

$V_2 = 110$ km/h

$A = [(g_2 - g_1] = [-2.5-2] = 4.5\%$

$S_{100} = 205.0$ m $S_{110} = 246.4$ m

$K_{100} = 105$ m/%A $K_{110} = 151$ m/%A

$L = KA = 105(4.5)$ $L = KA = 151(4.5)$

$= 472.5$ m $= 697.5$ m

Unit 2

G. continued...

Assume S<L $L = AS^2/404$

$S100 = \sqrt{472.5(404)/4.5}$ $= 205.96$ m ok

$S110 = \sqrt{697.5(404)/4.5}$ $= 250.23$ m ok

Difference = 697.5 - 472.5 = 225.0 m

Unit 2

H. Minimum curve length

$L_m = 0.6\ V_m = 0.6(100) = 60$ m

I. Length of curve in "G" for V=110 km/h to allow passing sight distance?

Assume S<L $L = AS^2/946$

$L = 4.5(728)^2/946 = 2521.07$ m

Unit 2

J. Desirable length of curve

$A = [0.5-(-2.8)] = 3.3$

assume S<L

$L = AS^2/(120+3.5S)$

$= 3.3(168.7)^2 / (120+3.5(168.7))$

$= 93916.977 / 710.45 = 132.19$ m ~ 132 m

$K_{90} = 40$ m/K

$L=KA=40(3.3) = 132$ .... use 135 m

Unit 2

K. Minimum length of sag curve in "J"

$Lm = AV^2/395 = 3.3(90)^2/395$

$= 67.67$ m

L. Drainage area in hectares

1 mi² x 640 ac/mi² x0.4047 ha/ac = 259.01 ha

M. Bridge Clearance (nearest 0.1 m)

14.5 ft x 0.3048 m/ft = 4.4196 m ~ 4.4 m

Unit 2

N. Pavement and shoulder widths

Pavement 22 ft x 0.3048 m/ft = 6.7 m

Shoulder 8 ft x 0.3048 m/ft = 2.4 m

O. No particular answer

P. Station Conversion

1. $67550.25 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{1 \text{ m}}{39.37 \text{ in}} = 205+89.36 \text{ m}$

2. 675+50.25 (E) = 205+89.36 (m)

Unit 2

Q. Lengths of Div I and II

Div I	2269.50	Div II	2350.00
	-243.84		-2269.50
	2025.66		80.50

1. Total = 2025.66+80.50 = 2106.16 m

2. Revised EOP Sta. Div II

   1.5 mi x 1.609 km/mi = 2.4135 km

   Sta 2350.00+2413.50 = 4763.50

   =47+63.50 (m)

Unit 2

Q. Continued

3. Granular surfacing plate 2108

volume => 101607.63 - 101530.00 = 77.63 m

$$77.63 \text{ m} \times 0.155 \text{ m} \times 6 \text{ m} = 72.20 \text{ m}^3$$

mass => 4100 kg/m^3 x 72.20 m^3 = 296,020 kg

= 296.02 Mg

4. Granular subbase plate 2211

$$\begin{array}{r} 2269.50 \\ -\ 243.84 \\ \hline 2025.66 \text{ m} \end{array}$$

Unit 2

Q. Continued

5. Volume of special backfill plate 2209

   2350.00 - 2269.50 = 80.50 m

   80.50 m x 0.3 m x 5.7 m x 2 = 275.31 m^3

6. Area of concrete plate 2201

   102900.00
   -101618.33
   1281.67 m x 7.2 m = 9228.02 m^2

7. See quantity sheet

Unit 2

Q. Continued

8. Seed quantities (May 21 - July 20)

Oats	15.6 ha x 108 kg/ha =	1684.8 kg
Rye	15.6 ha x 39 kg/ha =	608.4 kg
Clover	15.6 ha x 6 kg/ha =	93.6 kg
Timothy	15.6 ha x 6 kg/ha =	93.6 kg

9. Length of type 1601, 750 mm pipe = 25.0 m

Unit 2

Q. Continued

10. Volume of class 10 and unsuitable

Class 10 == 6819 m^3

Unsuitable == 1921 m^3

11. Special ditch elevations

Sta 5+00 elev = 443.10 m

Sta 6+00 elev = 441.10 m

Unit 3 - Bridge Design

- ✦ Topic Covered
- ✦ Hard Conversion Concerns
- ✦ Practical Bridge Design Applications

Unit 3

A. Bridge length

2 @ 30'6" => 30 ft x 12 in/ft+6= 366 in

2 x (366 in x 25.4 mm/in) = 18592.8 mm

1@ 39'0" => 39 ft x 12 in/ft x 25.4 mm/in

= 11887.2 mm

total = 30480.0 mm

B. Concrete strength

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= 27.58 MPa

 Rounded to 30 MPa overstates by +9%

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C. Rebar

$4\%/m^2 = 0.04 \times 1000 \times 1000 = 400\ mm^2$

1. #10M $400/100 = 4/m^2$
2. #30M $400/700 = 1/m^2$

Unit 3

D. Culvert Quantities

1. Concrete volume

   $1.610\ m^3/m \times 20\ m = 32.2\ m^3$

2. Steel mass

   $176.4\ kg/m \times 20\ m = 3528\ kg$

3. Steel mass change

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   $3666\ kg - 3528\ kg = 138\ kg$

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= 8.27 MPa

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1. Outer R

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   Inner R

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2. Bar length

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Inlet

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Outlet

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3.5 x 0.006 = 0.021 m

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21 mm < 25 mm

Unit 3

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1. Cast Iron

   $0.010 \text{ m} \times 0.005 \text{ m} \times 30 \text{ m} \times 7210 \text{ kg/m}^3$

   $= 10.82 \text{ kg}$

2. Steel

   $0.022 \text{ m} \times 0.10 \text{ m} \times 25.5 \text{ m} \times 7850 \text{ kg/m}^3$

   $= 440.38 \text{ kg}$

Unit 3

J. Gutter Elevation

0.08 x 5.60 m = 0.448 m ~ 0.45 m

Elev = 474.25 - 0.45 = 473.80 m

Elev = 474.25 + 0.45 = 474.70 m

K. Nail length

2 x 2.5 x 75 mm = 375 mm

Unit 3

L. Concrete temperature

$(95^{o}F-32)/1.8 = 35^{o}C > 32^{o}C$ no, reject

M. Curing compound amount

$55.40\ m \times 13.5\ m / 3.3\ m^2/L = 226.64\ L$

Unit 3

N. Gutter elevations

Top of slab centerline elevation

248.60 m + 0.250 m = 248.85 m

Centerline elevations at each end

248.85 m + 20 m (0.02) = 249.25 m

248.85 m - 20 m (0.02) = 248.45 m

Gutter elevations

249.25 m - 6.75 m (0.02) = 249.11 m

248.45 m - 675 m (0.02) = 248.31 m

Unit 3

O. Pipe length

$L = 13 + (848.5-838.0)(3) + (848.5-837.5)(3)$

$= 13 + 10.5(3) + 11(3) = 77.5$ m

P. Pipe spacing

1.2 m x 0.5 = 0.60 m

0.60 m < 1 m   use 0.6 m spacing

Unit 3

Q. Pile Bearing

$$P = [2.5WH/(S+8.9)][W/(W+M)]$$
$$= [\ 2.5\ (2500)(0.6)/(22+8.9)][2500/(2500+1200)]$$
$$= 121.359(0.67567)$$
$$= 81.9986 \text{ kN}$$
$$\sim 82 \text{ kN}$$

Unit 4 - Record Keeping

- ✦ Topics Covered
- ✦ Notation
- ✦ Prefixes
- ✦ Spacing and Capitalization
- ✦ Spelling and Pluralization
- ✦ Decimal markers and Spacing
- ✦ Powers of Ten

Rules review

- ✦ **name vs. symbol meter m**
- ✦ **prefix mega or bigger**
  - ✓ symbol is capital, name is small letter
- ✦ **combine prefix with name or symbol**
  - ✓ no hyphen or spaces
- ✦ **plurals at end of names not symbols**
- ✦ **spacing: 37.5 km**

Rules review continued

- ✦ **volume and area**
  - ✓ square meter(s) not meters squared
  - ✓ symbol use superscript number m^2
- ✦ **decimal and commas**
  - ✓ Iowa DOT will use period for decimal and commas to group by threes
  - ✓ Example: 123,456.789

    (Note: SI would be 123 456,789)

Rules review continued

- powers of ten examples

1300 m = 1.3 x 10^3 m = 1.3 km

17,500,000 Pa = 17.5 x 10^6 Pa = 17.5 MPa

0.075 Mg = 75 x 10^{-3} Mg = 75 kg

Multiplication and Division

Multiplication

- ✓ use dot in middle of symbol
- ✓ use hyphen in written text

✦ **Example:**

N ∘ m

newton-meter

Division

- ✓ use slash in middle of symbol
- ✓ use slash in written text (or per)

✦ **Example:**

m/s

meters/second

meters per second

Practice Writing In Pairs

Write in both number symbol and number written name format:

number	unit of measure
34 and 1/3	KILOMETERS
75.3	millimeters cubed per sec
237657.5	PASCALS
107000000	GRAM in MEGAGRAMS
0.0076	LITERS in terms of MILLILITERS

Practice Writing Solutions

34.33 km	34.33 kilometers
75.3 mm^3/s	75.3 cubic millimeters per second
237,657.5 Pa	237,657.5 pascals
237.6575 kPa	237.6575 kilopascals
107 Mg	107 megagrams
7.6 mL	7.6 milliliters

Worksheet Answers

1) Which is the correct symbol for megapascals?

A. Mpa

B. MPa

C. mPa

D. mPA

Worksheet Answers

2) What is the correct symbol for cubic millimeters?

A. cu. mm.

B. mm^3

C. cmm

D. mm ^{3}

Worksheet Answers

3) Which is not a correct SI plural?

A. 44.65 m

B. 5.4 kilopascal

C. Eighteen cubic millimeters

D. 149 MNs

Worksheet Answers

4) Which of the following is the correct representation of degrees Celsius?

A. 42.5^{o}c

B. 42.5 ^{o}C

C. 42.5 ^{o}c

D. 42.5^{o}C

Worksheet Answers

5) Which of the following is correct?

A. $19mm^3$

B. 448 cmm

C. 18 Mn

D. 55.7 kPa

Worksheet Answers

6) Which is the proper expression for kilometers per hour?

A. 75 KPH

B. 75 Km/H

C. 75 km/h

D. 75 km/hr

Worksheet Answers

7) Which of the following is equivalent to 1×10^4 square millimeters?

A. 10,000 mm^2

B. 1000 mm^2

C. 0.0001 mm^2

D. 0.001 mm^2

Worksheet Answers

8) Which of the following pairs of symbols and unit names is correct?

A. 17 MPa 17 Megapascals

B. 3434.6 N 3434.6 Newtons

C. 1.67 kg 1.67 kilograms

D. 2.3 mm 2.3 milli-meters

Worksheet Answers

9) Which of the following is a correct sentence for temperature?

A. The temp ... ten Degrees Celsius.

B. The temp ... ten degrees celsius.

C. The temp ... ten degrees Celsius.

D. The temp ... ten Degrees celsius.

Resources

- ✦ George Sisson, DOT Metric Coordinator, 239-1461
- ✦ AASHTO Green Book
- ✦ DOT Interim Metric Guide
- ✦ Conversion Calculators
- ✦ Numerous books, industry magazine articles, etc.

Worksheet Answers

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Worksheet Answers

10) Which of the following is correct?

A. .78 kg/m^2

B. 3.9 L's

C. 4.539 KPa

D. 3.87 ha

Worksheet Answers

11) Rounding

a) 34.876	34.88
b) 87.565	87.56
c) 1234	1230
d) 876.52	877
e) 0.2347	0.235

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