METRIC TRAINING

FOR THE TRANSPORTATION INDUSTRY

MODULE II

Construction and Maintenance Operations and Reporting

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 2 - Construction & Maintenance

Table of Contents

SI 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)

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

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.

A closer look at temperature

<u>degree Celsius</u>

water freezes = 0°C	32°F
water boils = 100°C	212°F

replaces Centigrade from older metric systems

room temperature = 20°C
normal body temperature = 37°C

A closer look at volume

<u>Liter - used for fluid volume</u>

Definition - one cubic decimeter

Symbol - L

one liter is approximately 1 quart + 1/4 cup

<u>Other units of volume</u>

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

<u>Other volumes (non-fluid)</u>

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

Estimating

Unit 2 - SI Applications in Construction Estimating 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 construction problems. Topics covered will include:

- Hard vs. Soft Conversion
- Use of Conversion Tables
- SI Construction Estimation 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

Construction Estimation Problems

A. Viewing the cover sheet of the US 75, Sioux County construction plans:

1. What is the total length of the project in meters, or kilometers?

2. What is the total length of the project if it was to be extended to the east boundary of Section 25?

	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 203-4 on Sheet C.02

LETTING DATE

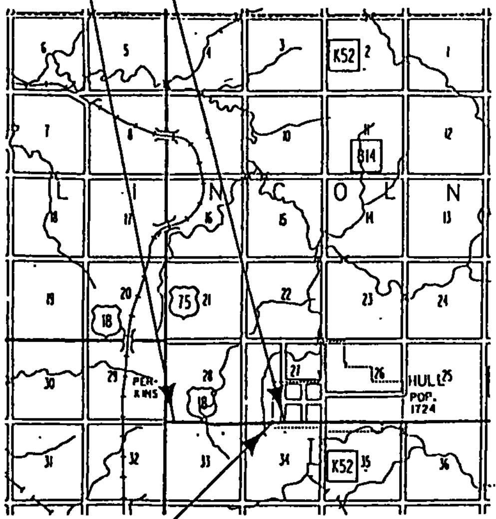
PCC PAVEMENT - GRADE/NEW
STP-18-1(999)--2C-84

SIOUX CO.

STA. 2+43.84
BEGIN PROJECT
& DIV. 1

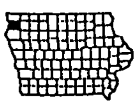
STA. 23+50.00
END DIV. 2
& PROJECT

T-97N



R-45W

STA. 22+69.50
END DIV. 1 &
BEGIN DIV. 2



LOCATION MAP SCALE
0 1 2 3 4 5
KILOMETERS

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

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.

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-37D	09-27-94
RA-53	06-06-95	RF-14	06-06-95	RH-45B	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	06-05-95
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

Iowa Department of Transportation
Project Development Division
AUTHORIZED FOR LETTING
DESIGN ENGINEER
Iowa Registration No. Date

JACOB D. RYDELL 98765 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

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
APPROVED

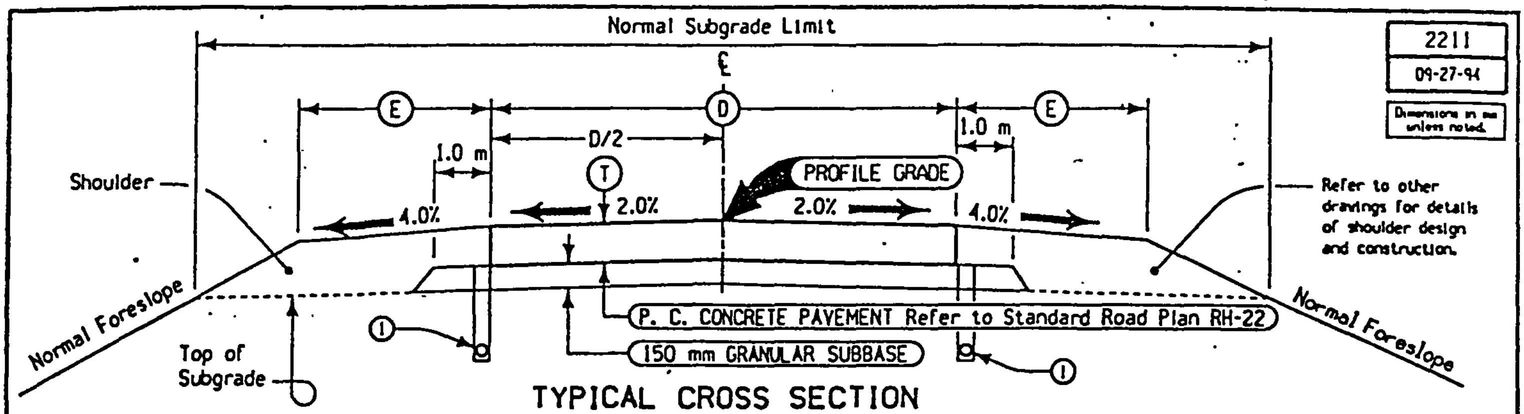
FOR THE DIVISION ADMINISTRATOR DATE

B. A portion of the typical section shown on page B.03 of the Sioux County plans is attached for reference in the calculations for the next three questions.

1. What is the volume of concrete materials to be placed between the stations shown in Plate 2211?

2. Utilizing Plate 2209, calculate the volume of special backfill material to be placed?

3. Calculate the volume of granular subbase materials to be placed according to the information provided in Plate 2211?



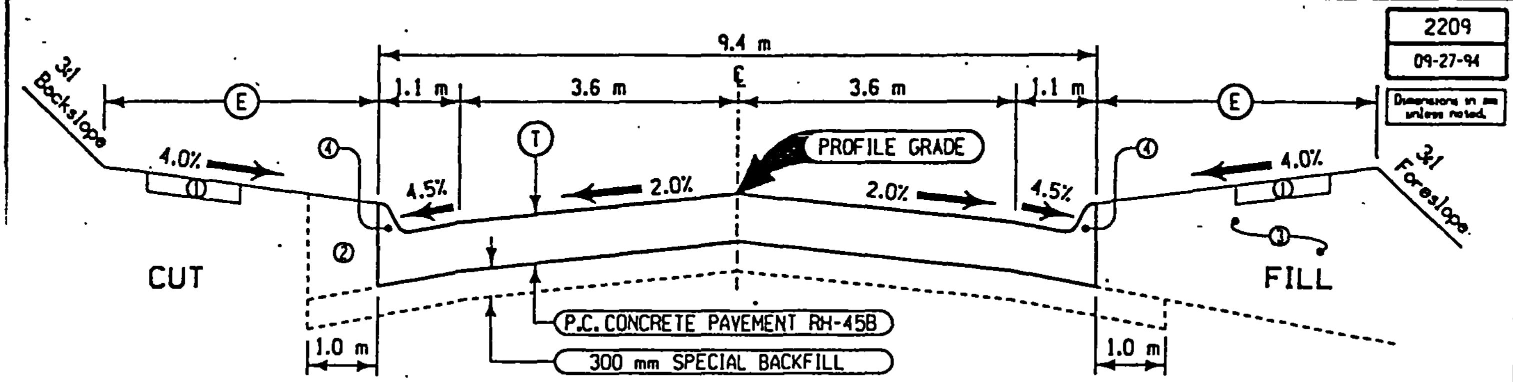
TYPICAL CROSS SECTION
2 LANE ROADWAY With 150 mm GRANULAR SUBBASE

Note:

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



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

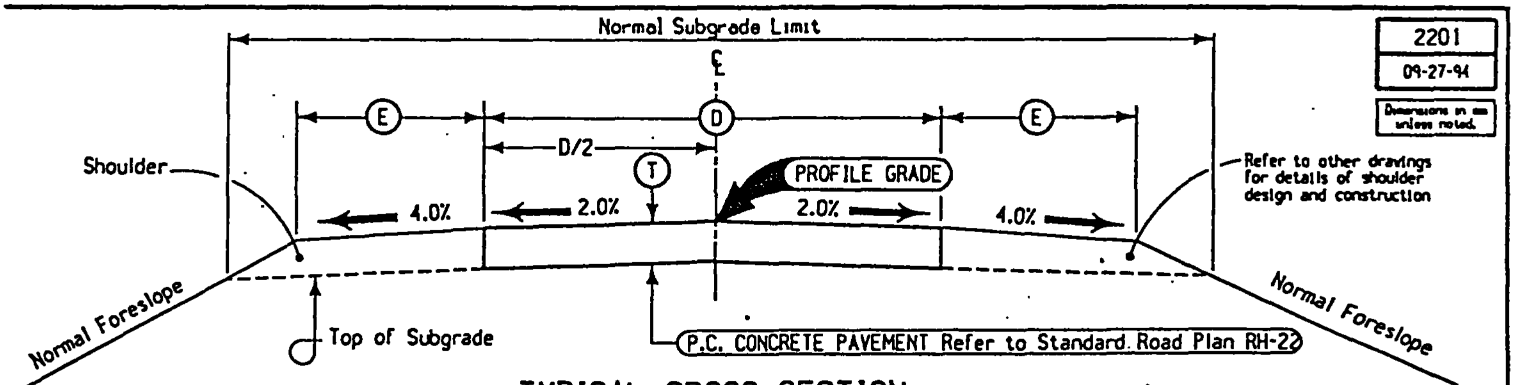
LOCATION			T	E
ROAD IDENTIFICATION	STATION TO STATION		mm	m
U.S. 18	22+69.50	23+50.00	250	5.4

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



TYPICAL CROSS SECTION
2 LANE ROADWAY

Note:

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

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

C. Utilizing the Estimated Project Quantities, Plate 100-1B in the Sioux County plans and your current knowledge of construction prices, estimate the cost of each item and the total project cost?

ESTIMATED PROJECT QUANTITIES

100-1B
09-27-94

CONSTRUCTION USE ONLY	ITEM CODE	ITEM	UNIT	QUANTITIES ESTIMATED DIVISION 1	DIVISION 2	TOTAL	AS BUILT DIVISION 1	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

Field Construction

Unit 3

Unit 3 - SI Applications in Field Construction Activities

This part of the workshop will provide a participants with a chance to work through sample conversion problems related to field construction activities.

A. An 8 cubic meter truck load of concrete is to be batched using the Iowa DOT C-4WR-C mix shown in the following table. What is the total mass and volume of each material used in the load?

SSD Weights		Unit Volume	Density	Batch Mass
Cement	229 kg	0.10 m^3	298.6 kg/m^3	299 kg/m^3
Fly Ash	54 kg	0.02 m^3	54.0 kg/m^3	54 kg/m^3
Water	204 kg	0.20 m^3	204.5 kg/m^3	171 kg/m^3
Fine Aggregate	822 kg	0.31 m^3	822.0 kg/m^3	847 kg/m^3
Coarse Aggregate	819 kg	0.31 m^3	818.9 kg/m^3	827 kg/m^3
Water Reducer	691 ml	0.00 m^3	0.0 kg/m^3	691 ml
Air	6.00%	0.06 m^3	0.0 kg/m^3	6.00%
		1.00 m3	2197.9 kg/m3	

B. The End of Project Station (English) shown on an "as built" plan is 149+15.75.

1. Convert this station to international units to begin the next project as the BOP Station.

2. Express the information expressed in part 1 as a station equation

C. Using the attached reinforcing steel bar information sheet, determine the metric total weight (mass) of the following list of bars?

1. 10 each 10M bars, 7.8 m in length

2. 8 each 30M bars, 9.2 m in length

3. 15 each 45M bars, 6.5 m in length

4. What is the difference in diameter and cross section area between the 15M and 55M bar?

D. You are purchasing right of way for construction. The area to be purchased is 9 m wide and 30.25 m in length. How many hectares will you purchase?

E. After working in the sun your body attains a temperature of 40 °C. Should you consult a doctor?

ASTM A615 CHART FOR REINFORCING STEEL BARS

Inch-Pound Bar Size Designation	Nominal Weight lb./ft.	Nominal Weight (kg/m)	Nominal Dimensions: Diameter in.	Nominal Dimensions: Diameter (mm)	Nominal Dimensions: Cross Sectional Area in^2	Nominal Dimensions: Cross Sectional Area (mm^2)
#3	0.376	(.560)	0.375	(9.5)	0.11	(71)
#4	0.668	(.994)	0.500	(12.7)	0.20	(129)
#5	1.043	(1.552)	0.625	(15.9)	0.31	(200)
#6	1.502	(2.235)	0.750	(19.1)	0.44	(284)
#7	2.044	(3.042)	0.875	(22.2)	0.60	(387)
#8	2.670	(3.974)	1.000	(25.4)	0.79	(510)
#9	3.400	(5.060)	1.128	(28.7)	1.00	(645)
#10	4.303	(6.404)	1.270	(32.3)	1.27	(819)
#11	5.313	(7.907)	1.410	(35.8)	1.56	(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 mm^2	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

F. A 9 cubic meter truck load of construction materials (density of 314 kg/m^3) has a mass of ________ Mg.

G. The horizontal scale on your construction plans is 1:250. What distance is associated with 36 mm on the plans?

H. White pigmented curing compound is to be applied at a minimum rate of 0.5 L/m^2. How many liters are required for 1 km of 7.2 m wide pavement?

I. Express the following sieve measurements as a meter decimal form.

1. 75 µm

2. 600 µm

3. 2.36 mm

J. Asphalt continuous mix pugmill mixing times are calculated from the following equation:
Mix time (s) = pugmill contents (kg)/pugmill output (kg/s) The project pugmill has a capacity of 120,120 g and an output rate of 2.86 kg/s. What is the mixing time?

K. Compute the quality index for a sample lot of asphaltic concrete that has an average thickness of 78 mm, minimum thickness of 70 mm, maximum thickness of 84 mm and a design thickness of 76.2 mm using the following equation.

QI(mm)=[average thickness-(design thickness-12.7)]/[maximum thickness-minimum thickness]

L. Maintenance is applying a sealcoat and the supervisor wants to order cover aggregate to treat the surface at a rate of 16 kg/square meter. How many Mg should be ordered for an area 1.00 km in length and 6.00 m wide?

M. Granular surfacing 150 mm in depth is required for a temporary driveway, 0.5 km in length, and 5 m wide. How may cubic meters of material should be ordered?

N. The water cement ratio for a bridge deck project (D-57) concrete is established at a maximum of 0.437 kg water/kg of cement.

1. The contractor mixed 1400 g of water with 4.00 kg of cement. Should you accept the mix?

2. Will your decision change if 800 g of water is added to the mix at the construction site?

O. A formwork live load (vertical) for concrete with a density of 2400 kg/m^3 is being designed for a bridge deck of 305 mm in depth. What is the load due to the concrete per square meter of supporting formwork?

P. Rigid pipe culverts require 50 mm of sand cushion for type "B" bedding and a shaped concave saddle to a depth of 15% of the pipe diameter. A 600 mm diameter pipe is to be placed. How deep (mm) must the saddle be to accommodate the sand and craddle requirements?

Q. A metric concrete pipe extension (downstream end) is desired for attachment to a 30 inch diameter pipe. What diameter metric pipe will be required for this purpose?

Metric Concrete Pipe Sizes
(From ASTM C14 M and ASTM C76 M)

Metric Size mm	Allowable Dimensions Minimum mm	Allowable Dimensions Maximum mm	English Equivalent inches
100	100	110	4
150	150	160	6
200	200	210	8
250	250	260	10
300	300	310	12
375	375	390	15
450	450	465	18
525	525	545	21
600	600	620	24
675	675	695	27
750	750	775	30
825	825	850	33
900	900	925	36
1050	1050	1080	42
1200	1200	1230	48
1350	1350	1385	54
1500	1500	1540	60
1650	1650	1695	66
1800	1800	1850	72
1950	1950	2000	78
2100	2100	2155	84
2250	2250	2310	90
2400	2400	2465	96
2550	2550	2620	102
2700	2700	2770	108
2850	2850	2925	114
3000	3000	3080	120
3150	3150	3235	126
3300	3300	3390	132
3450	3450	3540	138
3600	3600	3695	144

R. An existing cross road pipe, 120 ft. in length, is to be replaced. What metric length of pipe should the engineer order for this purpose?

S. What is the minimum length of horizontal curve radius required for a vehicle design speed of 110 km/hr with a maximum superelevation rate of 8% and a assumed friction factor of 0.10.

$R_m \text{ (minimum)} = V^2/127[(e \text{ maximum}/100)+f \text{ maximum}]$

T. Compute the length of spiral required for the curve developed in question S.

$L_m = 0.0702(V^3)/RC$ Given C=1

U. Embankment layers can be deposited in layers up to 200 mm in loose thickness. A fill 21 meters in height is to be constructed. How many layers would be required if the material is assumed to have a 0.0% shrinkage factor?

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

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

Unit 4 - SI Applications in Record Keeping

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

Intended Precision

"What 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

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!

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 Metric Tables

SI Metric 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	°C	K ($t°C = t$ 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	°	(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)

References

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 2 - Construction & Maintenance 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

Total Project Length

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

1. Total Length = 2025.66+80.50 = 2106.16 m
2. Revised Length
   approximately 2.5 miles added
   2.5 mi x 1.609 km/mi = 4.0225 km

   2106.16 + 4022.50 = 6128.66 m

Unit 2 - B

1. Concrete volume Plate 2211
   Sta 2269.50
   -Sta 243.66 m
   2025.66 m x 8.2 m x 0.250 m = 4151.60 m^3

2. Special Backfill Volume Plate 2209
   Sta 2350.00
   -Sta 2269.50
   80.50 m x11.4 m x 0.300 m = 275.31 m^3

Unit 2 - B

3. Granular Subbase - Volume Plate 2211
   Sta 2269.50
   -Sta 243.84
   2025.66 m
   Vol = (2025.66 m)[(0.15 m x 10.2 m)+
   (2 x 0.5 x 0.15 m x 0.15 m)]
   = 2025.66 m [(1.53 + 0.0225)m^2]
   = 3144.83 m^3

Unit 2 - C

Bid prices will vary with individual area.

Unit 3

A. Mass and Volume of each material

Material	Batch Mass	Truck Mass	Batch Vol.	Truck Vol.
Cement	229 x 8 =	1832kg	0.10 x 8 =	0.80 m^3
Fly Ash	54 x 8 =	432 kg	0.02 x 8 =	0.16 m^3
Water	204 x 8 =	1632 kg	0.20 x 8 =	1.60 m^3
Fine Agg.	822 x 8 =	6576 kg	0.31 x 8 =	2.48 m^3
Coar.Agg.	819 x 8 =	6552 kg	0.31 x 8 =	2.48 m^3
Water Reducer	--		--	* see note
Air	--		0.06 x 8 =	0.48 m^3
		17,024 kg		8.00 m^3

Note: water reducer vol = 691 ml x 8 = 5528 ml

Metric Training for the Transportation Industry
Module 2 - Construction & Maintenance Answers

Unit 3

B. BOP Station
1. 14915.75 ft x 12 in/ft x 1 m/39.37 in = 4546.33 m
2. Sta 45 + 46.33 (m) = Sta 149 + 15.75 (E)

C. Metric Bars
1. 10 x 7.8 m x 0.785 kg/m = 61.23 kg
2. 8 x 9.2 m x 5.495 kg/m = 404.43 kg
3. 15 x 6.5 m x 11.775 kg/m = 1148.06 kg
4. Dia 55 M = 56.4 mm Area 55M = 2500 mm²
   Dia 15 M = 16.0 mm Area 15M = 200 mm²
   Difference= 40.4 mm = 2300 mm²

Unit 3

D. ROW Area
9.0 m x 30.25 m = 272.25 m²
272.25 m² / 10000 (m²/ha) = 0.027 ha

E. Temperature
(40°C x 1.8) + 32 = 104°F Yes

F. Truck Mass
9 m³ x 314 kg/m³ = 2826 kg
= 2.83 Mg

G. Scale
250 x 36 mm = 9000 mm = 9 m

Unit 3

H. Curing Compound
1000 m x 7.2 m x 0.5 L/m² = 3600 L

I. Sieve sizes
1. 0.000075
2. 0.000600
3. 0.00236

J. Pugmill mix time
120.12 kg/(2.86 kg/s) = 42 s

Unit 3

K. Quality Index
$QI_m = \frac{[78\text{ mm} - (76.2\text{ mm} - 12.7\text{ mm})]}{[84\text{ mm} - 70\text{ mm}]}$
= 1.04 mm

L. Seal Coat Aggregate Mass
1000 m x 6.00 m x 16 kg/m² = 96000 kg
= 96 Mg

M. Granular surfacing volume
500 m x 5 m x 0.150 m = 375 m³

Unit 3

N. Water cement ratio
1. 1.4 kg/4 kg = 0.35 0.35 < 0.437 accept
2. 2.2 kg/4 kg = 0.55 0.55 > 0.437 reject

O. Formwork load
2400 kg/m³ x 0.305 m = 732 kg/m²

P. Pipe Craddle
50 mm + (0.15 x 600 mm) = 140 mm

Q. Pipe Size
30 in x 25.4 mm/in = 762 mm
Use Iowa DOT chart ... round up to 775 mm

Unit 3

R. Pipe Length
120 ft x 0.3048 m/ft = 36.576 m = 36.6 m

S. Curve Radius
Rm = 110²/127(0.08+0.10) = 529.31 m
build R = 530 m

T. Spiral Curve Length
Lm = 0.0702 (110)3/529.31 (1)
= 176.52 m build Lm = 180 m

U. Constructed Fill Layers
21 m /0.200 m = 105 lifts

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 2

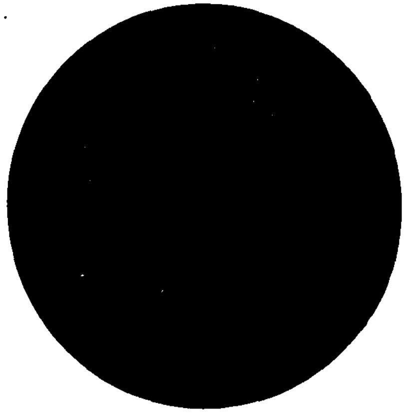
Created by:
Karen Zunkel &
Jim Cable
Iowa State University

Workshop Overview

- ✦ Unit 1 - History and SI Basics
- ✦ Unit 2 - SI Applications in Construction Estimating
- ✦ Unit 3 - SI Applications in Field Construction
- ✦ 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"

$$1\ lb_f \quad = \quad 0.4536\ kg$$

(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 - Estimating Topics

Topics Covered

- Conversion Types and Factors
- Construction Estimation 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 $\pm$ 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

Total Project Length

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

1. Total Length = 2025.66+80.50 = 2106.16 m
2. Revised Length

   approximately 2.5 miles added

   2.5 mi x 1.609 km/mi = 4.0225 km

   2106.16 + 4022.50 = 6128.66 m

Unit 2 - B

1. Concrete volume Plate 2211

   Sta 2269.50

   -Sta 243.66 m

   2025.66 m x 8.2 m x 0.250 m = 4151.60 m^3

2. Special Backfill Volume Plate 2209

   Sta 2350.00

   -Sta 2269.50

   80.50 m x11.4 m x 0.300 m = 275.31 m^3

Unit 2 - B

3. Granular Subbase - Volume Plate 2211

Sta 2269.50
-Sta 243.84
2025.66 m

$$\text{Vol} = (2025.66\ \text{m})[(0.15\ \text{m} \times 10.2\ \text{m}) + (2 \times 0.5 \times 0.15\ \text{m} \times 0.15\ \text{m})]$$

$$= 2025.66\ \text{m}\ [\ (1.53 + 0.0225)\text{m}^2]$$

$$= 3144.83\ \text{m}^3$$

Unit 2 - C

Bid prices will vary with individual area.

Unit 3 - Field Construction

Topic Covered

✦ Practical Construction Applications

Unit 3

A. Mass and Volume of each material

Material	Batch Mass	Truck Mass	Batch Vol.	Truck Vol.
Cement	299 x 8 =	2392 kg	0.10 x 8 =	0.80 m^3
Fly Ash	54 x 8 =	432 kg	0.02 x 8 =	0.16 m^3
Water	171 x 8 =	1368 kg	0.20 x 8 =	1.60 m^3
Fine Agg.	847 x 8 =	6776 kg	0.31 x 8 =	2.48 m^3
Coar.Agg.	827 x 8 =	6616 kg	0.31 x 8 =	2.48 m^3
Water Reducer	--		--	* see note
Air	--		0.06 x 8 =	0.48 m^3
		17,584 kg		8.00 m^3

or 17.584 Mg (Note: water reducer vol = 691 ml x 8 = 5528 ml)

Unit 3

B. BOP Station

1. 14915.75 ft x 12 in/ft x 1 m/39.37 in =
   4546.33 m
2. Sta 45 + 46.33 (m) = Sta 149 + 15.75 (E)

C. Metric Bars

1. 10 x 7.8 m x 0.785 kg/m = 61.23 kg
2. 8 x 9.2 m x 5.495 kg/m = 404.43 kg
3. 15 x 6.5 m x 11.775 kg/m = 1148.06 kg
4. Dia 55 M = 56.4 mm Area 55M = 2500 mm^2
   Dia 15 M = 16.0 mm Area 15M = 200 mm^2
   Difference= 40.4 mm = 2300 mm^2

Unit 3

D. ROW Area

$9.0 \text{ m} \times 30.25 \text{ m} = 272.25 \text{ m}^2$

$272.25 \text{ m}^2 / 10000 \text{ (m}^2\text{/ha)} = 0.027 \text{ ha}$

E. Temperature

$(40^\circ\text{C} \times 1.8) + 32 = 104^\circ\text{F}$ Yes

F. Truck Mass

$9 \text{ m}^3 \times 314 \text{ kg/m}^3 = 2826 \text{ kg}$

$= 2.83 \text{ Mg}$

Unit 3

G. Scale

250 x 36 mm = 9000 mm = 9 m

H. Curing Compound

1000 m x 7.2 m x 0.5 L/m^2 = 3600 L

I. Sieve sizes

1. 0.000075
2. 0.000600
3. 0.00236

Unit 3

J. Pugmill mix time

120.12 kg/(2.86 kg/s) = 42 s

K. Quality Index

$$QI_m = \frac{[78\text{ mm} - (76.2\text{ mm} - 12.7\text{ mm})]}{[84\text{ mm} - 70\text{ mm}]}$$

$$= 1.04\text{ mm}$$

L. Seal Coat Aggregate Mass

$$1000\text{ m} \times 6.00\text{ m} \times 16\text{ kg/m}^2 = 96000\text{ kg}$$

$$= 96\text{ Mg}$$

Unit 3

M. Granular surfacing volume

$500 \text{ m} \times 5 \text{ m} \times 0.150 \text{ m} = 375 \text{ m}^3$

N. Water cement ratio

1. 1.4 kg/4 kg = 0.35 $0.35 < 0.437$ accept
2. 2.2 kg/4 kg = 0.55 $0.55 > 0.437$ reject

O. Formwork load

$2400 \text{ kg/m}^3 \times 0.305 \text{ m} = 732 \text{ kg/m}^2$

Unit 3

P. Pipe Craddle

50 mm + (0.15 x 600 mm) = 140 mm

Q. Pipe Size

30 in x 25.4 mm/in = 762 mm

Use Iowa DOT chart ... round up to 775 mm

R. Pipe Length

120 ft x 0.3048 m/ft = 36.576 m = 36.6 m

Unit 3

S. Curve Radius

$Rm = 110^2/127(0.08+0.10) = 529.31$ m

build R = 530 m

T. Spiral Curve Length

$Lm = 0.0702\ (110)^3/529.31\ (1)$

$= 176.52$ m build Lm = 180 m

U. Constructed Fill Layers

21 m /0.200 m = 105 lifts

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

$1300\ m = 1.3 \times 10^{3}\ m = 1.3\ km$

$17{,}500{,}000\ Pa = 17.5 \times 10^{6}\ Pa = 17.5\ MPa$

$0.075\ Mg = 75 \times 10^{-3}\ Mg = 75\ kg$

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:

<u>number</u>	<u>unit of measure</u>
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. 42.5oc

B. 42.5 oC

C. 42.5 oc

D. 42.5oC

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 $1x10^4$ 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.

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

Resources

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