Effective use of Python in Transportation Engineering Teaching

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Outline

- Transportation engineering teaching for civil engineering students
- Objective
- What is expected?
- Current Situation
- Coding of the Concept
- Examples
- Benefits

Transportation engineering teaching in civil engineering

- Third year course
- Fundamentals of transportation engineering in one semester
- Most of the students have no background on transportation engineering
- Use of commercial software is limited:
  - Budget
  - Commercial software are specialized so one software will not cover all the subjects
  - Python is versatile and flexible so any problem can be solved

Objective

- Using a software tool that will help the students to
  - Understand the concept
  - Check their hand calculation accuracy
  - Use software for what-if analysis

What is expected?

- The students need to learn, understand and use engineering principles to solve the problems.

Current Situation

- Visual examples as given in textbooks are limited
- Doing what if analysis may take away precious teaching time
- The students may have problem in
  - Understanding the problem, how to solve it?
  - Selecting the appropriate formula for the solution
  - Using the right unit in the calculations (i.e., radians vs degrees)

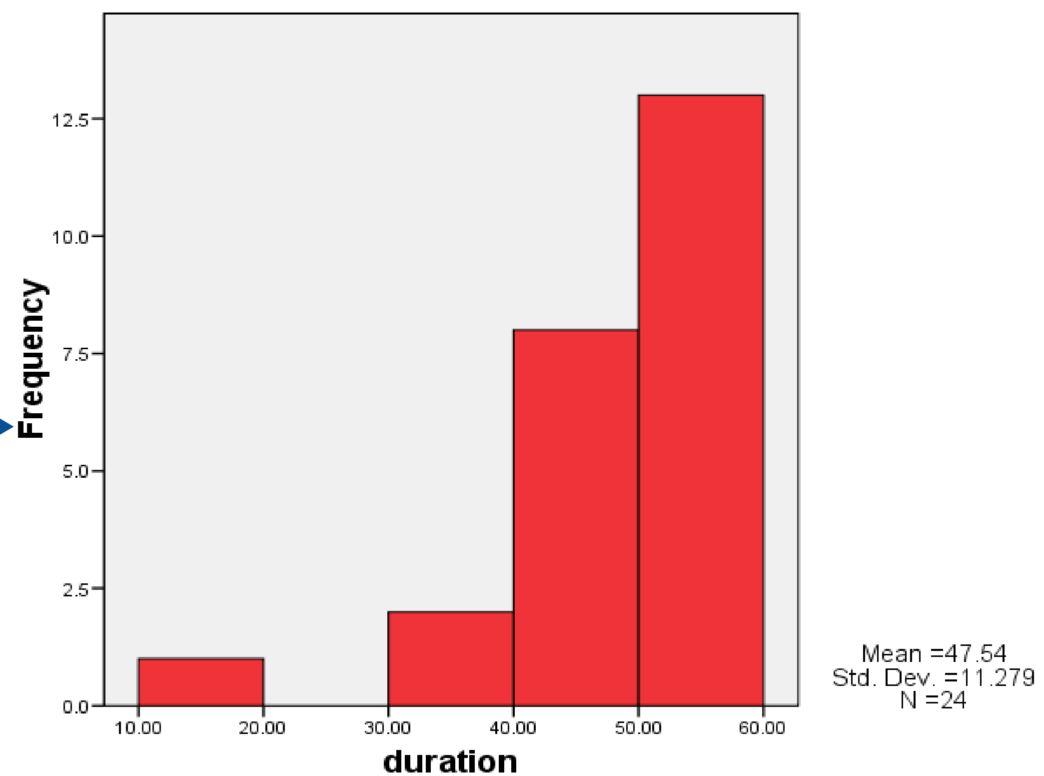
Current Situation

- Surveying students on learning styles
  - Visual learning style is mainly used
- Problem solving duration estimation
  - Hand calculation (with a calculator)
  - Using Python
- Post-test survey of students

Current Situation

- Surveying students on learning styles
  - Visual is most preferred
- Problem solving duration estimation
  - Hand calculation (with a calculator)
  - Using Python

Duration in minutes for one problem



Current Situation

- Surveying students on learning styles
  - Visual is most preferred
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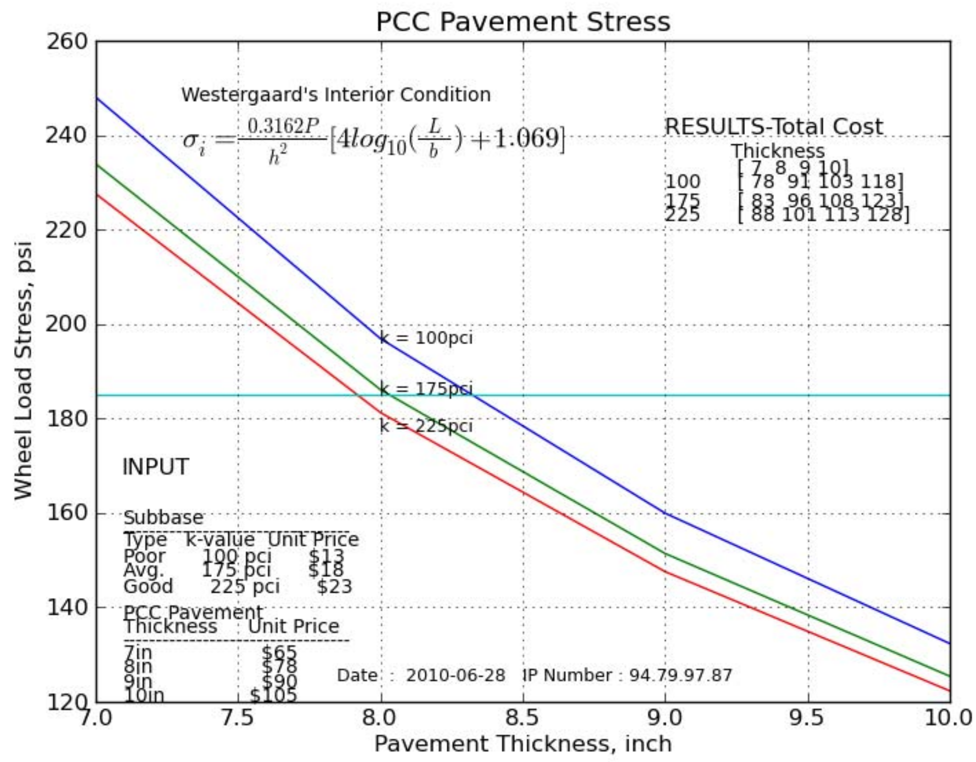
  - Using Python

Average duration = 5 min



Coding of the concept

- Equations
- Python Code

Coding of the concept-equations

Spiral Curve

Input:
Δ, R_c, L_s

$$A = \sqrt{L_s R_c} \longrightarrow$$

$$X_s = L_s - \frac{L_s^5}{40A^4}$$

$$Y_s = \frac{L_s^3}{6A^2} - \frac{L_s^7}{336A^6}$$

$$\longrightarrow$$

$$\theta_s = \frac{L_s}{2R_c}$$

$$p = Y_s - R_c(1 - \cos\theta_s)$$

$$k = X_s - R_c \sin\theta_s$$

$$T' = (R_c + p)\tan\left(\frac{\Delta}{2}\right)$$

$$L_c = R_c \Delta_{rad} - L_s$$

$$d = \tan^{-1}\left(\frac{Y}{X}\right)$$

$$c = \sqrt{X^2 + Y^2}$$

Coding of the concept-Python Modules

- Python 2.6.5
- Numpy
- Matplotlib

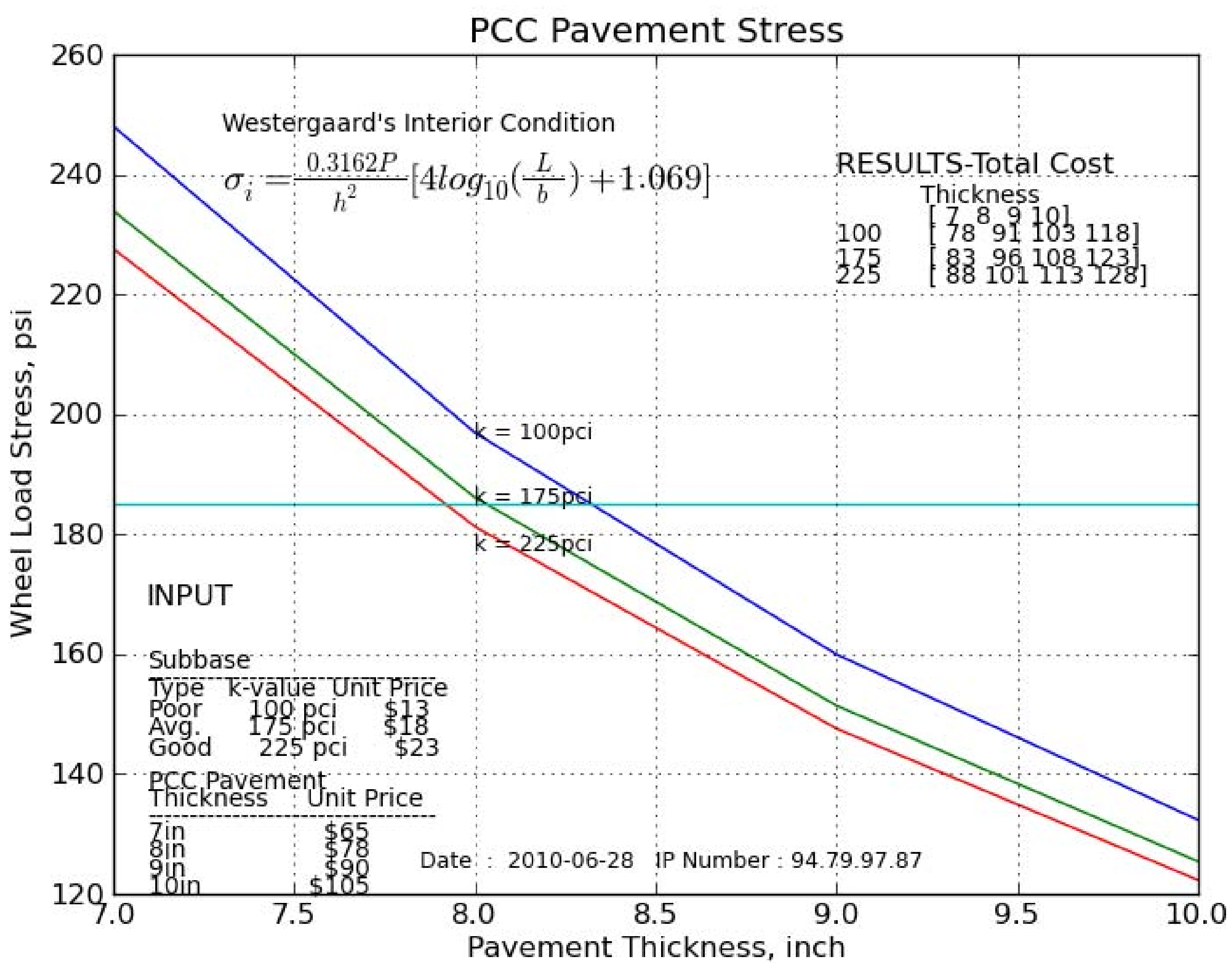
Coding of the concept-Python Functions

- Python 2.6.5
- Numpy
  - Degree to radian conversion (pi)
  - Array calculations
  - Array statistics – average(), mean (), std()
  - Linear algebra – lstsq()
  - Trigonometric functions

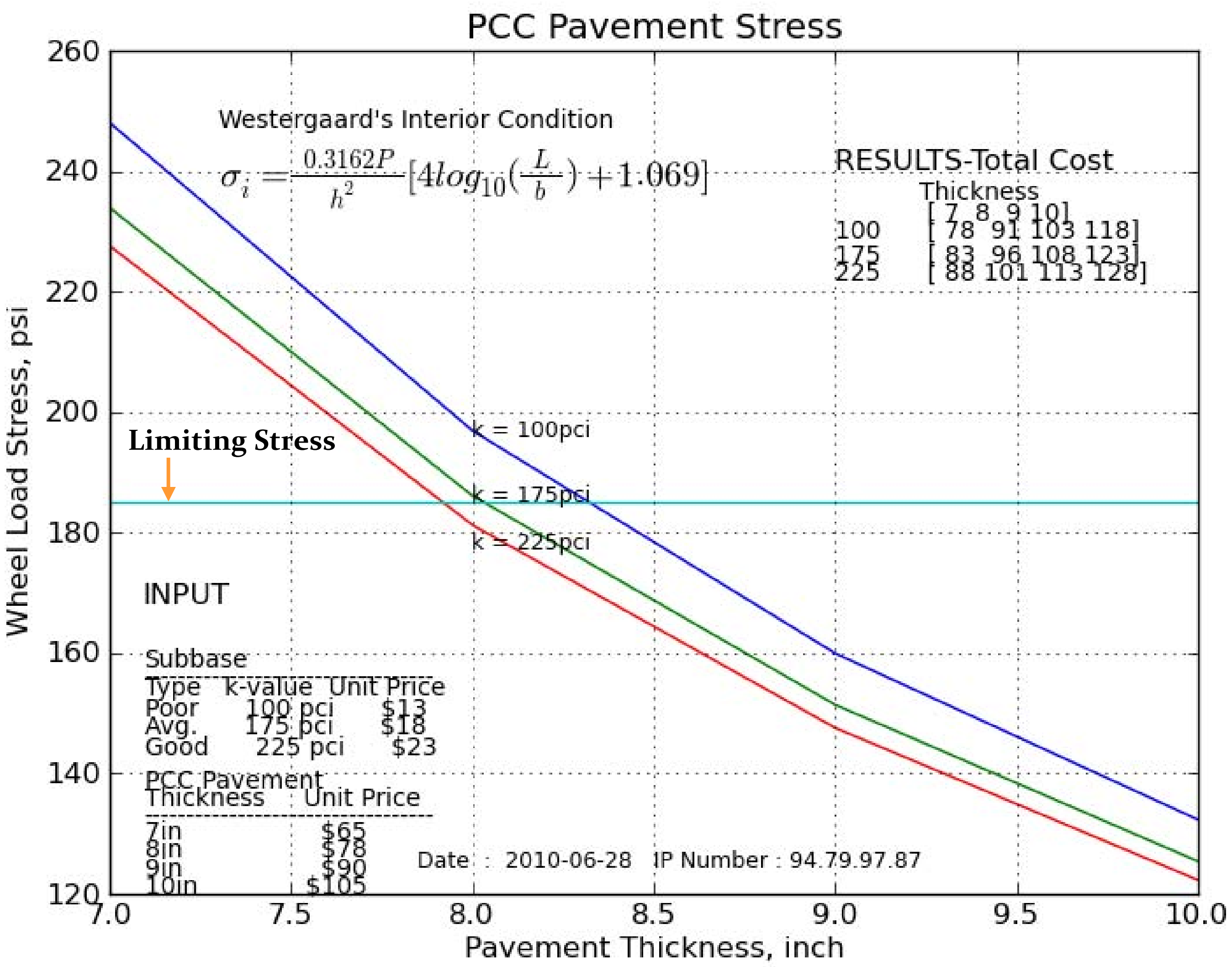
Examples

Portland Cement Concrete Pavement Thickness Design based on Costs of subbase and pavement

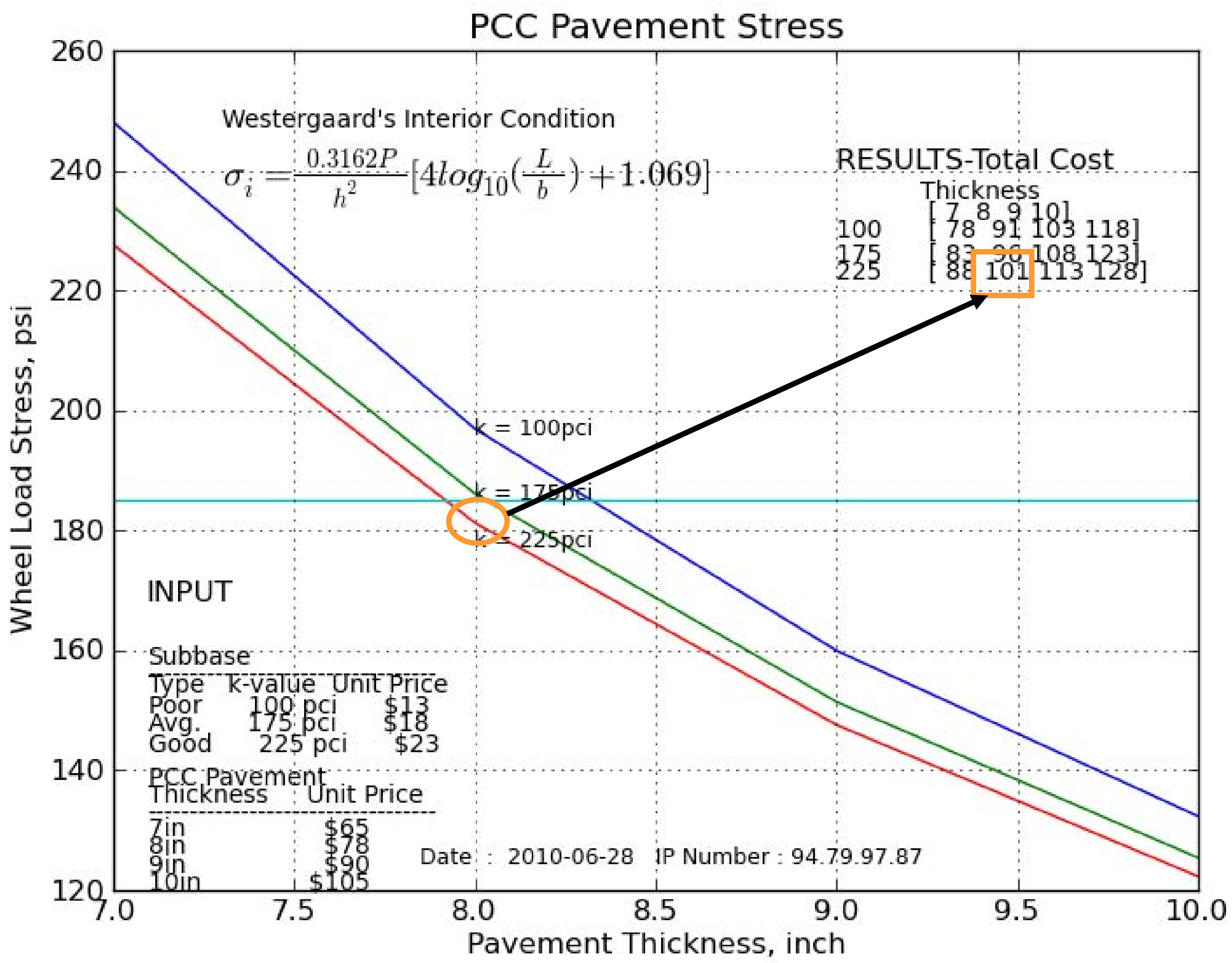
Vertical Curve – Sag or Crest, finding the lowest or highest point



PCC Pavement Stress
Westergaard's Interior Condition
$\sigma_i = \frac{0.3162P}{h^2}[4log_{10}(\frac{L}{b}) + 1.069]$
RESULTS-Total Cost
Thickness
[7 8 9 10]
100 [78 91 103 118]
175 [83 96 108 123]
225 [88 101 113 128]
k = 100pci
k = 175pci
k = 225pci
INPUT
Subbase
Type k-value Unit Price
Poor 100 pci $13
Avg. 175 pci $18
Good 225 pci $23
PCC Pavement
Thickness Unit Price
7in $65
8in $78
9in $90
10in $105
Date : 2010-06-28 IP Number : 94.79.97.87
Wheel Load Stress, psi
Pavement Thickness, inch
260
240
220
200
180
160
140
120
7.0
7.5
8.0
8.5
9.0
9.5
10.0



PCC Pavement Stress
Westergaard's Interior Condition
$\sigma_i = \frac{0.3162P}{h^2}[4log_{10}(\frac{L}{b}) + 1.069]$
RESULTS-Total Cost
Thickness
[7 8 9 10]
100 [78 91 103 118]
175 [83 96 108 123]
225 [88 101 113 128]
Limiting Stress
k = 100pci
k = 175pci
k = 225pci
INPUT
Subbase
Type k-value Unit Price
Poor 100 pci $13
Avg. 175 pci $18
Good 225 pci $23
PCC Pavement
Thickness Unit Price
7in $65
8in $78
9in $90
10in $105
Date : 2010-06-28 IP Number : 94.79.97.87
Wheel Load Stress, psi
Pavement Thickness, inch



PCC Pavement Stress
Westergaard's Interior Condition
$\sigma_i = \frac{0.3162P}{h^2}[4log_{10}(\frac{L}{b}) + 1.069]$
RESULTS-Total Cost
Thickness
[7 8 9 10]
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Thickness Unit Price
7in $65
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9in $90
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Date : 2010-06-28 IP Number : 94.79.97.87
Wheel Load Stress, psi
Pavement Thickness, inch

```
CIVL361 TRANSPORTATION ENGINEERING
           Instructor: Dr. Mehmet M. Kunt


Computer Name:  datron-86c6bb17    Date   :    2010-06-28
IP Number is :  94.79.97.87

                   Input Variables
=============================================================
g1 =  -2.7 %;  g2 =  1.5 %;   Length of the Curve =  3.5 sta
=============================================================


                       RESULTS
===========================================================
THIS IS A  SAG VERTICAL CURVE

Rate of change of grade is 1.200 %/Sta
Location of  lowest  point is 2.25 sta from BVC
Station of PI =  150 + 0 sta
Elevation of PI =  25.0 m
Station of BVC =  148 + 25 sta
Elevation of BVC =  29.73 m
Station of  lowest  point =  150 + 50 sta
Elevation of  lowest  point =  26.69 m
===========================================================
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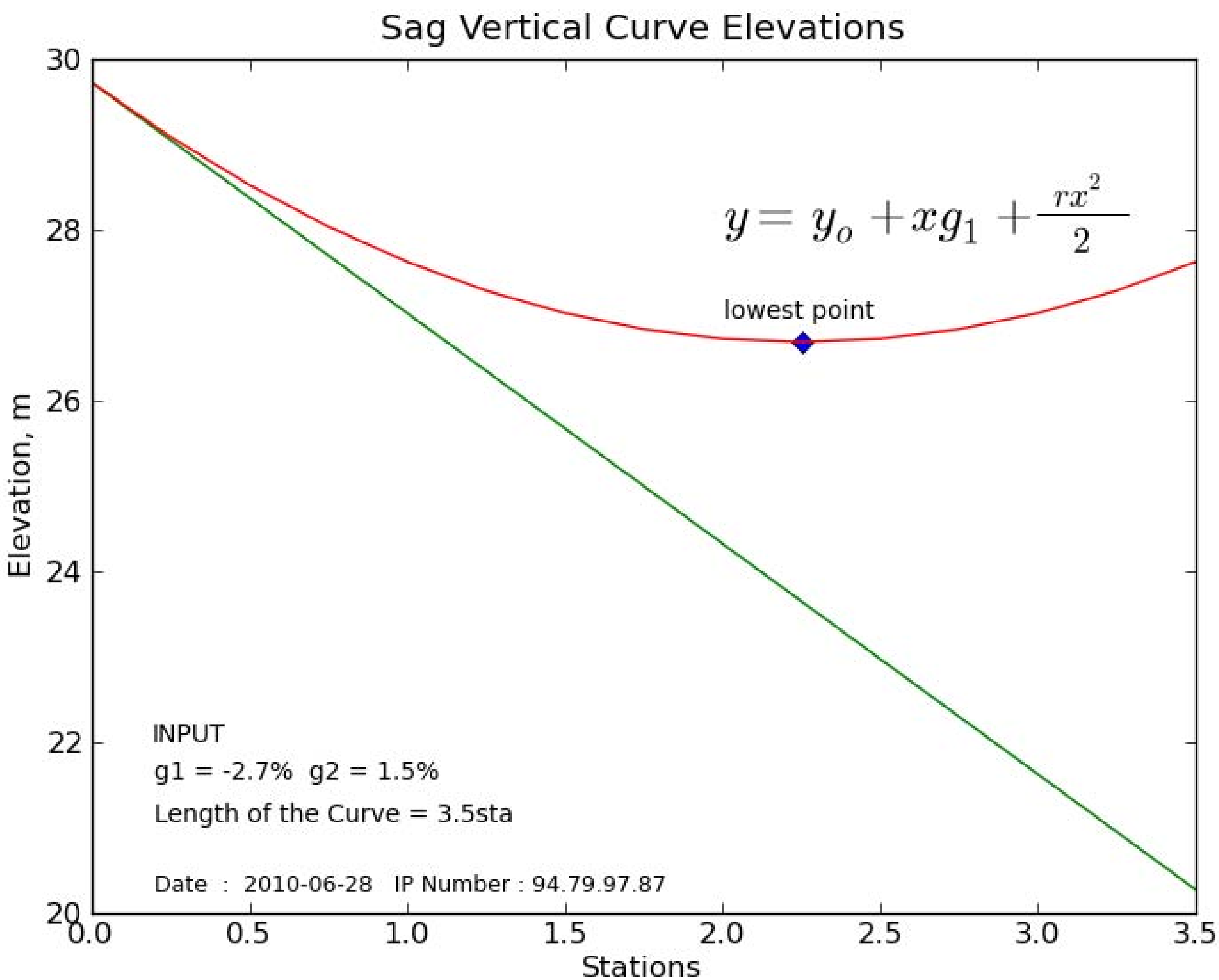


Sag Vertical Curve Elevations
30
28
26
24
22
20
Elevation, m
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Stations
$y = y_o + xg_1 + \frac{rx^2}{2}$
lowest point
INPUT
g1 = -2.7% g2 = 1.5%
Length of the Curve = 3.5sta
Date : 2010-06-28 IP Number : 94.79.97.87

CIVL361 TRANSPORTATION ENGINEERING
Instructor: Dr. Mehmet M. Kunt

Computer Name: datron-86c6bb17 Date : 2010-06-28
IP Number is : 94.79.97.87

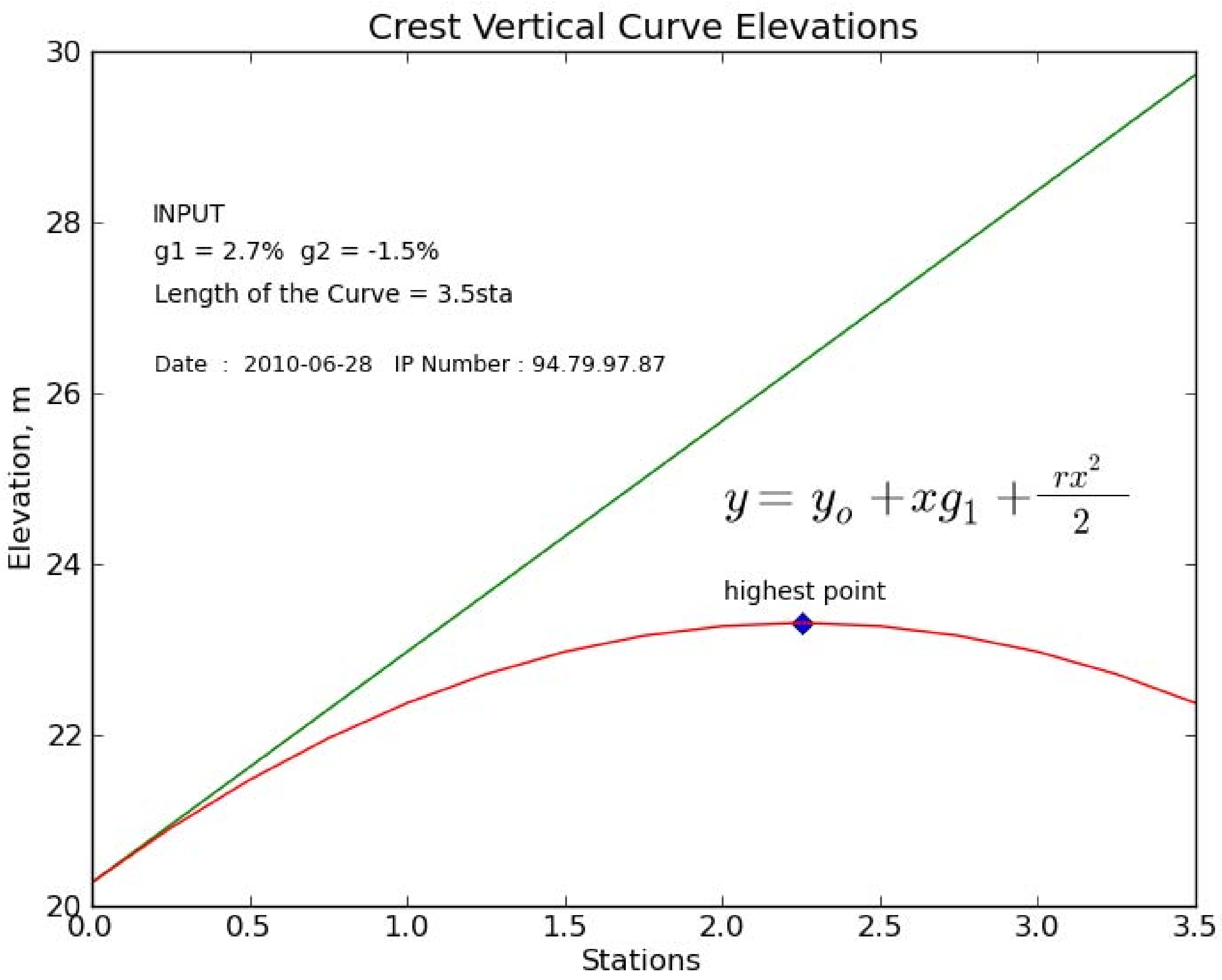
Input Variables

==
g1 = 2.7 %; g2 = -1.5 %; Length of the Curve = 3.5 sta
==

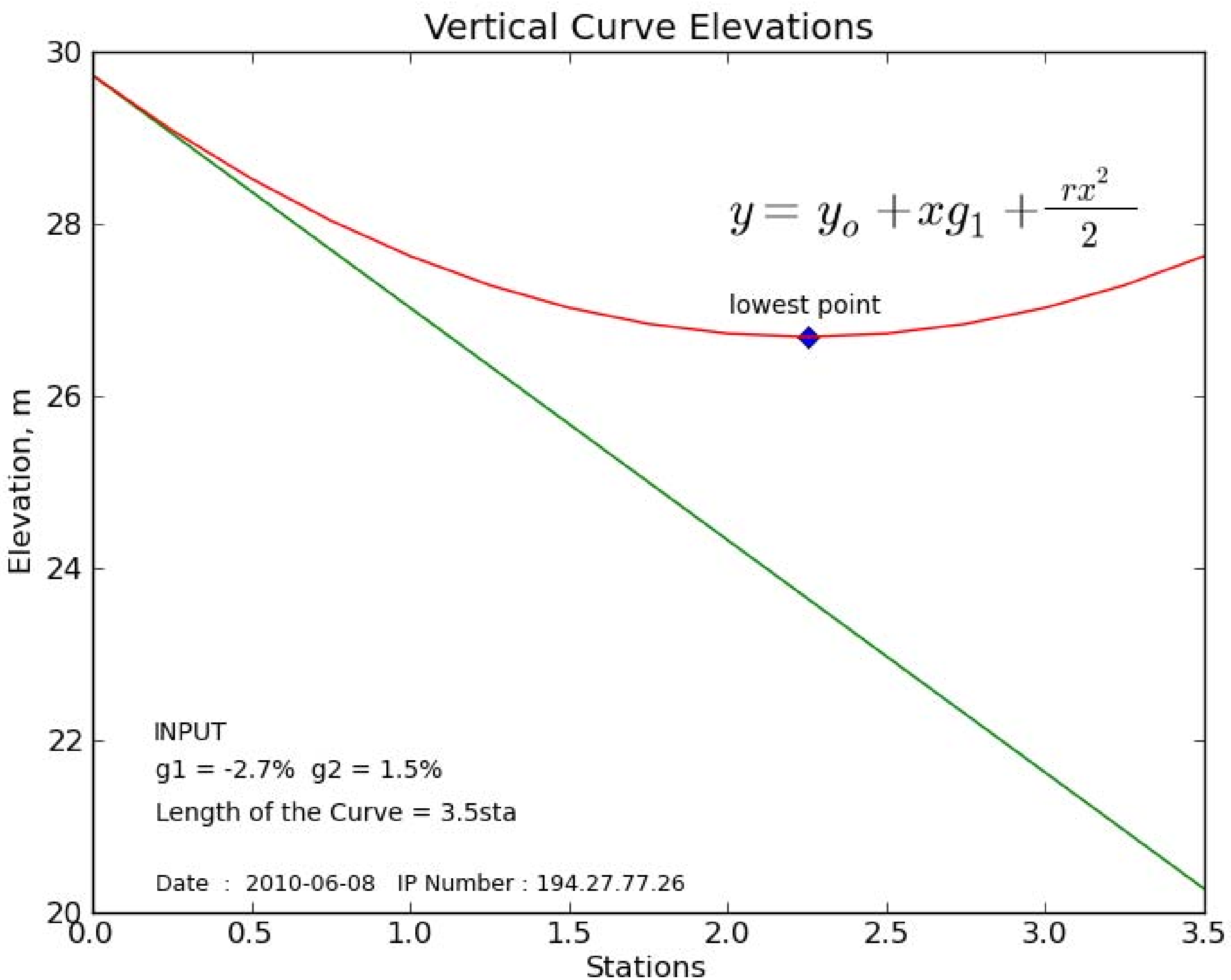
RESULTS

==
THIS IS A CREST VERTICAL CURVE

Rate of change of grade is -1.200 %/Sta
Location of highest point is 2.25 sta from BVC
Station of PI = 150 + 0 sta
Elevation of PI = 25.0 m
Station of BVC = 148 + 25 sta
Elevation of BVC = 20.27 m
Station of highest point = 150 + 50 sta
Elevation of highest point = 23.31 m
==



Crest Vertical Curve Elevations
INPUT
g1 = 2.7% g2 = -1.5%
Length of the Curve = 3.5sta
Date : 2010-06-28 IP Number : 94.79.97.87
$y = y_o + xg_1 + \frac{rx^2}{2}$
highest point
Elevation, m
Stations
30
28
26
24
22
20
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5



Vertical Curve Elevations
$y = y_o + xg_1 + \frac{rx^2}{2}$
lowest point
INPUT
g1 = -2.7% g2 = 1.5%
Length of the Curve = 3.5sta
Date : 2010-06-08 IP Number : 194.27.77.26
Elevation, m
Stations
30
28
26
24
22
20
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

Benefits

- Time savings (one problem for 24 students saved two-8 hr day)
- Efficient, accurate, reliable problem solving environment
- Allows the instructor to discuss more cases, advanced issue
- Allows build-up of knowledge without forcing the students to memorize the examples or assumptions
- The attention will be on using the right input and obtaining the right decisions

Thanks for your attention