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

- Mean = 47.54
- Std. Dev. = 11.279
- N = 24
Current Situation

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

Average duration = 5 min
Coding of the concept

- Equations
- Python Code
Coding of the concept-equations

Spiral Curve

Input: \( \Delta, R_c, L_s \)

\[
A = \sqrt{L_s R_c}
\]

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

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

\[
\theta_s = \frac{L_s}{2R_c}
\]

\[
p = Y_s - R_c \left(1 - \cos \theta_s \right)
\]

\[
k = X_s - R_c \sin \theta_s
\]

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

\[
L_c = R_c \Delta_{rad} - L_s
\]

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

\[
c = \sqrt{X^2 + Y^2}
\]
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

Limiting Stress

Westergaard's Interior Condition

$$\sigma_i = \frac{0.3162P}{h^2}[4\log_{10}(\frac{L}{b}) + 1.069]$$

RESULTS - Total Cost

<table>
<thead>
<tr>
<th>Thickness</th>
<th>78</th>
<th>91</th>
<th>103</th>
<th>118</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>101</td>
<td>101</td>
<td>101</td>
<td>101</td>
</tr>
<tr>
<td>175</td>
<td>108</td>
<td>108</td>
<td>108</td>
<td>108</td>
</tr>
<tr>
<td>225</td>
<td>113</td>
<td>113</td>
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<td>113</td>
</tr>
</tbody>
</table>

INPUT

<table>
<thead>
<tr>
<th>Subbase Type</th>
<th>K-value</th>
<th>Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>100 psi</td>
<td>$13</td>
</tr>
<tr>
<td>Avg</td>
<td>175 psi</td>
<td>$18</td>
</tr>
<tr>
<td>Good</td>
<td>225 psi</td>
<td>$23</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>PCC Pavement Thickness</th>
<th>Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 in</td>
<td>$65</td>
</tr>
<tr>
<td>9 in</td>
<td>$69</td>
</tr>
<tr>
<td>10 in</td>
<td>$105</td>
</tr>
</tbody>
</table>

Date: 2010-06-28
IP Number: 94.79.97.87
PCC Pavement Stress

Westergaard's Interior Condition

$$\sigma_i = \frac{0.3162P}{h^2} \left[4 \log_{10}\left(\frac{L}{b}\right) + 1.069\right]$$

RESULTS - Total Cost

<table>
<thead>
<tr>
<th>Thickness</th>
<th>$78$, $91$, $103$, $118$</th>
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</thead>
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<td>$78$, $91$, $103$, $118$</td>
</tr>
<tr>
<td>$175$</td>
<td>$88$, $101$, $113$, $128$</td>
</tr>
<tr>
<td>$225$</td>
<td>$88$, $101$, $113$, $128$</td>
</tr>
</tbody>
</table>

INPUT

<table>
<thead>
<tr>
<th>Subbase Type</th>
<th>K-value (pci)</th>
<th>Unit Price</th>
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</thead>
<tbody>
<tr>
<td>Poor</td>
<td>100</td>
<td>$13</td>
</tr>
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<td>Avg</td>
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</tr>
<tr>
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<th>Unit Price</th>
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<tbody>
<tr>
<td>7 in</td>
<td>$65</td>
</tr>
<tr>
<td>8 in</td>
<td>$60</td>
</tr>
<tr>
<td>9 in</td>
<td>$60</td>
</tr>
<tr>
<td>10 in</td>
<td>$105</td>
</tr>
</tbody>
</table>

Date: 2010-06-28  IP Number: 94.79.97.87
Input Variables

\[ g_1 = -2.7 \; \%; \quad g_2 = 1.5 \; \%; \quad \text{Length of the Curve} = 3.5 \; \text{sta} \]

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
Sag Vertical Curve Elevations

\[ y = y_o + xg_1 + \frac{rx^2}{2} \]

lowest point

**INPUT**

\[ g_1 = -2.7\% \quad g_2 = 1.5\% \]

Length of the Curve = 3.5 sta

**Date** : 2010-06-28  **IP Number** : 94.79.97.87
Input Variables

\[ g_1 = 2.7\%; \quad g_2 = -1.5\%; \quad \text{Length of the Curve} = 3.5\;\text{sta} \]

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
INPUT
\( g_1 = 2.7\% \quad g_2 = -1.5\% \)
Length of the Curve = 3.5 sta

Date : 2010-06-28    IP Number : 94.79.97.87

\[ y = y_0 + x g_1 + \frac{r x^2}{2} \]

highest point
Vertical Curve Elevations

\[ y = y_o + x g_1 + \frac{r x^2}{2} \]

lowest point

INPUT
\( g_1 = -2.7\% \)  \( g_2 = 1.5\% \)
Length of the Curve = 3.5sta

Date : 2010-06-08  IP Number : 194.27.77.26
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