Load Deflection Prediction of Helicals Using Hyperbolic & Machine Learning Methods



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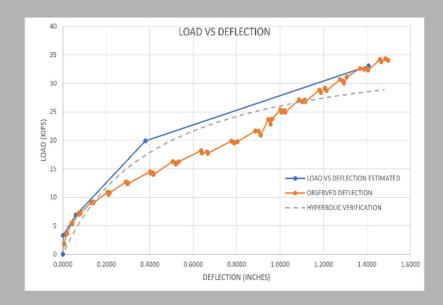


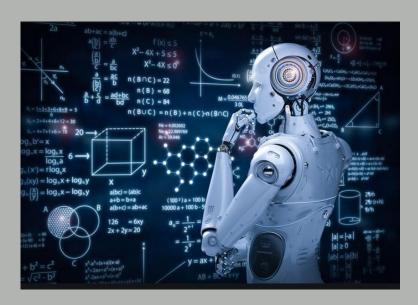
OUTLINE

- 1. Introduction & Problem Statement <<
- 2. Hyperbolic Methodology
- 3. Machine Learning Methodology
- 4. Q&A + Thank You

INTRODUCTION & PROBLEM STATEMENT

- 1. Prediction of the ultimate capacity of a Helical has been studied but not predicting the deflection under loading
- 2. Superstructure Structural Engineer's often specify deflection values that the Foundations must adhere to making predicting deflection under loading a valuable tool
- 3. Dr. Perko guided my doctoral research to begin to tackle this problem
- 4. Dr. Ahmadein helped me incorporate Machine Learning to tackle this problem to take advantage of modern technology



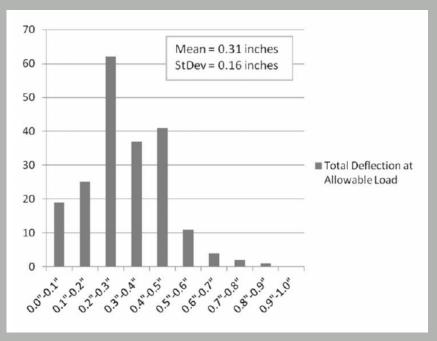


forbes.com

CURRENT HELICAL DEFLECTION RESEARCH

Cherry and Perko 2013 examined 202 load tests but did not create a predictive model. Dr. Perko wanted to continue this research and has provided guidance/mentoring

| Bearing Material | Compression (93 Tests) | | Ter | ision | Compression & Tension (202 Tests) | | |
|--------------------------|---------------------------|-----------------------|-----------|-----------------------|-----------------------------------|-----------------------|--|
| | | | (109 | Tests) | | | |
| | Mean (in) | Standard Deviation | Mean (in) | Standard Deviation | Mean (in) | Standard Deviation | |
| All (202 tests) | 0.22 | 0.14 | 0.24 | 0.14 | 0.23 | 0.14 | |
| Sand (76 Tests) | 0.27 | 0.15 | 0.27 | 0.17 | 0.27 | 0.16 | |
| Clay (89 Tests) | 0.17 | 0.10 | 0.21 | 0.11 | 0.20 | 0.10 | |
| Wx Bedrock (37 Tests) | 0.19 | 0.16 | 0.22 | 0.16 | 0.21 | 0.16 | |



Cherry and Perko (2013)

RAW DATA

| # of Tests | Size | Shape | | |
|-----------------------------|-------|--------|--|--|
| 9 Compression + 8 Tension | 1.5" | Square | | |
| 8 Compression + 9 Tension | 1.75" | Square | | |
| 66 Compression + 68 Tension | 2.88" | Round | | |
| 76 Compression + 73 Tension | 3.5" | Round | | |
| 10 Compression + 8 Tension | 4.25" | Round | | |
| 10 Compression + 8 Tension | 4.5" | Round | | |

179 Compression Tests + 174 Tension Tests

CTL Thompson (2007)

OUTLINE

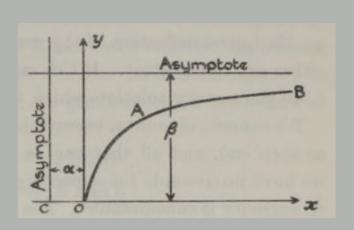
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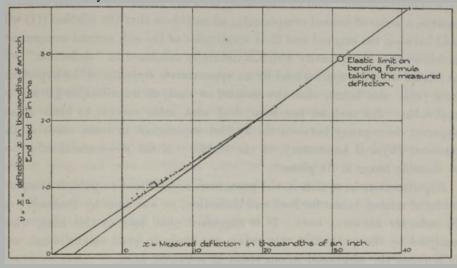
HYPERBOLIC METHOD

Equation of Hyperbola can be written as y = x / (a + bx)

Which can be rewritten as x/y = a + bx which is similar to y = mx + b an equation of a straight line which gives two parameters that can describe the deflection curve.

The Hyperbolic Method was pioneered in 1932 by Dr. Richard Southwell at Oxford University to Linearize non-linear data. This methodology was then applied to Helicals by Dr. Perko and this study.

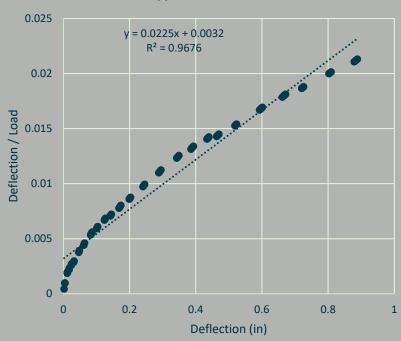


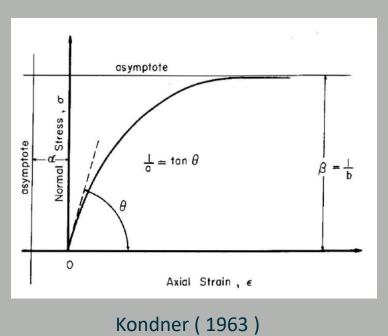


Stanwell (1932)

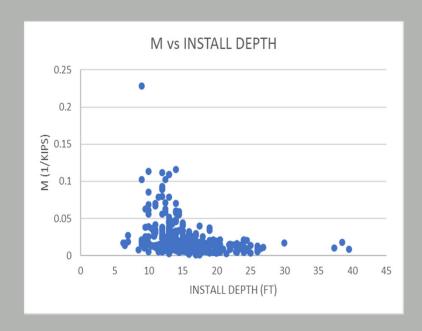
DATA ANALYSIS

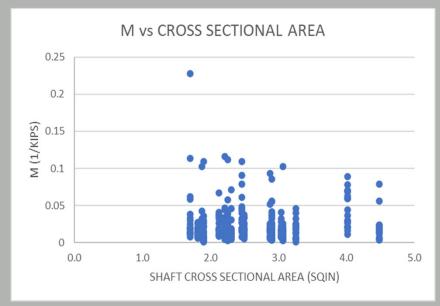
Perko Hyperbolic Fit Model





M & B vs PARAMETERS GRAPHS





55 different comparisons looked at for Global and per Soil Type Data

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CURRENT MACHINE LEARNING FOR DEEP FOUNDATION DEFLECTION RESEARCH

In 2018 for IFCEE Machairas and Iskander of NYU used Support Vector Machine Learning to evaluate 213 load tests from FHWA's Deep Foundation Load Test Database. They evaluated load capacity prediction using Machine Learning and did not look at predicting deflection

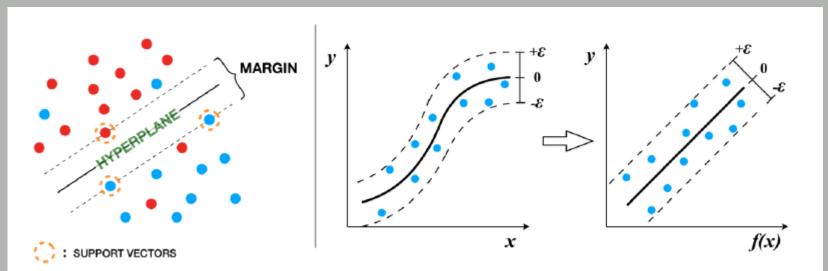


Figure 4. Schematic of SVM maximum margin optimization (LHS), transformation to a higher dimensional feature space where cost-dependent regression can occur (RHS)

(Machairas and Iskander, 2018)



Machine learning is programming computers to optimize a performance criterion using example data or past experience. -- Ethem Alpaydin

The goal of machine learning is to develop methods that can automatically detect patterns in data, and then to use the uncovered patterns to predict future data or other outcomes of interest.

-- Kevin P. Murphy

The field of pattern recognition is concerned with the automatic discovery of regularities in data through the use of computer algorithms and with the use of these regularities to take actions.

-- Christopher M. Bishop

IN A FUTURISTIC HOPE ...

Machine learning is about predicting the future based on the past.

-- Hal Daume III





Predicting Deflection Using Machine Learning

In order to predict deflection using Machine learning (ML) we use two famous regression ML algorithms

- DNN
- Random Forest

We then compare the performance of both algorithms with the hyperbolic method

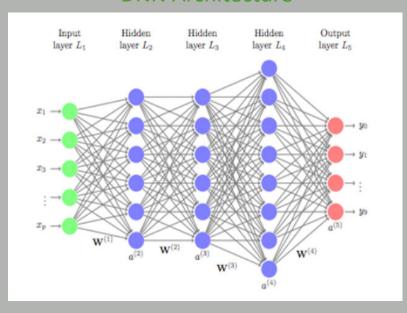
DEEP NEURAL NETWORK (DNN)

Advanced machine learning algorithms to implement complicated non linear relationships using trial and error

 It uses gradient descent and backward propagation to optimize weights of each layer to minimize cost function given the data

 Cost function in our case is Mean Square Error (MSE) between predicted deflection and actual deflection

DNN Architecture



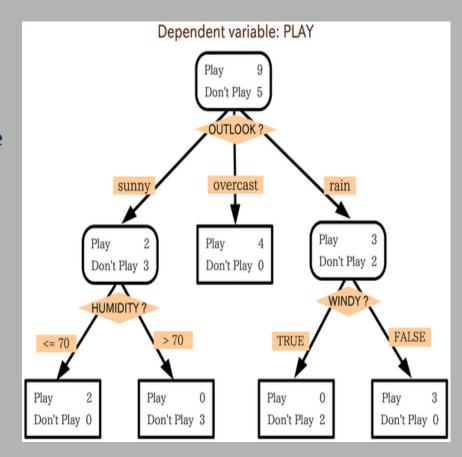
Boehmke and Greenwell (2020)

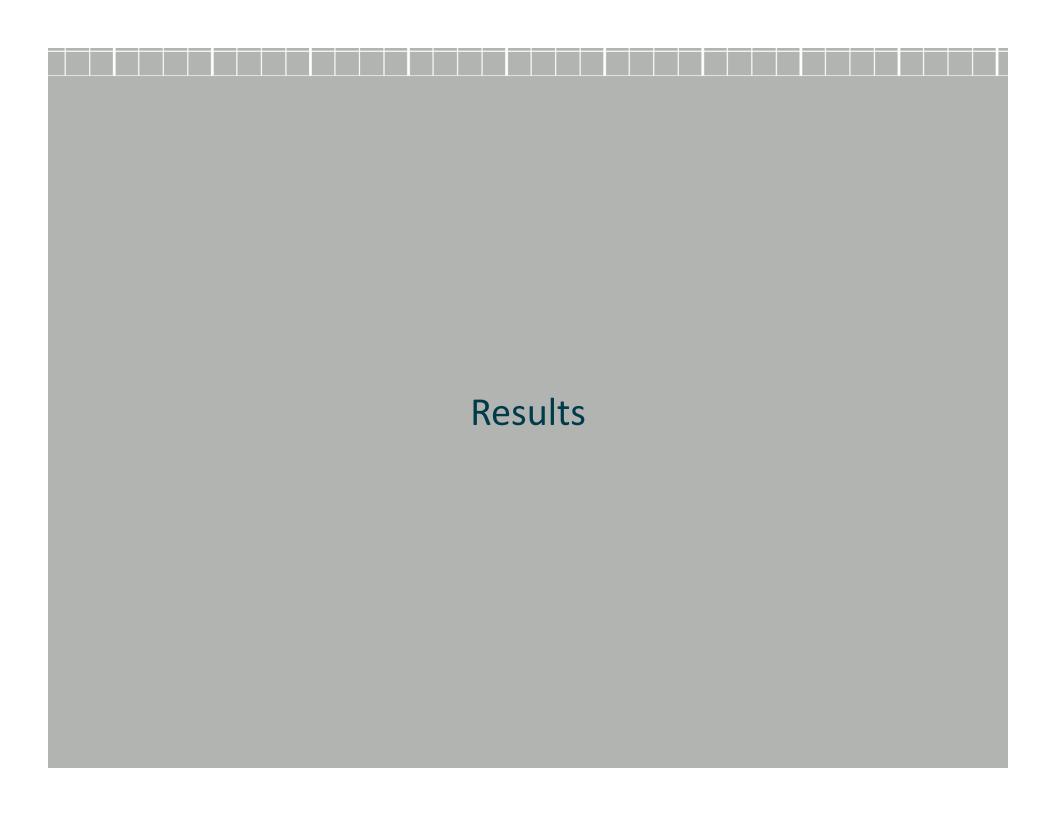
Geron (2017)

RANDOM FOREST MACHINE LEARNING

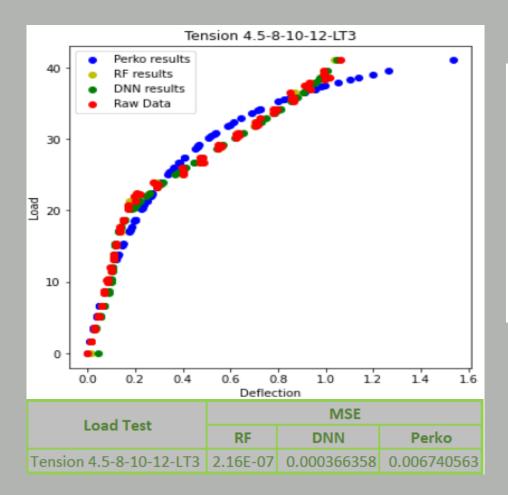
It is based on decision trees. In this case, the ML algorithm tries to find the best set of questions to split the data on and increase the information gained and minimize the cost function

Random forest is accurate as it works by growing randomly and independently many decision tree and takes majority vote





MACHINE LEARNING & MEAN SQUARE ERROR



Formula

$$ext{MSE} = rac{1}{n} \sum_{i=1}^n (Y_i - \hat{Y_i})^2$$

MSE = mean squared error

n = number of data points

 Y_i = observed values

 \hat{Y}_i = predicted values

Wikipedia (2021)

MACHINE LEARNING IS THE FUTURE OF NON-LINEAR ANALYSIS IN ENGINEERING

| | | MSE | | | Accuracy Ratios | | |
|-----------|---------------------------------|----------|----------|-------------|-----------------|----------------|---------|
| Load Test | test_sheet | MSE RF | MSE DNN | MSE Perko | DNN/Perko | RF/ Perko | RF/DNN |
| 0 | Compression-4.5-8-10-12-LC2 MAX | 0.000722 | 0.071656 | 0.143493121 | 3 | 199 | 100 |
| 1 | Compression 4.5 -14- LC1 | 1.46E-05 | 0.063422 | 0.099029653 | 2 | 6,787 | 4,347 |
| 2 | Compression 4.5 -10-12 LC2 | 5.68E-05 | 0.055272 | 11.23903788 | 204 | 197,708 | 973 |
| 3 | Compression 4.5-8-10-12-LC3 | 1.08E-05 | 0.03098 | 0.087350725 | 3 | 8,097 | 2,872 |
| 4 | Compression 4.5 8-BR1 | 0.000259 | 0.028227 | 0.029468521 | 2 | 114 | 109 |
| 5 | Compression 4.5-8- PC1 | 7.63E-06 | 0.047362 | 0.040341458 | 1 | 5,287 | 6,207 |
| 6 | Compression 4.5-10-12- PC2 | 2.43E-05 | 0.044864 | 0.051747143 | 2 | 2,128 | 1,845 |
| 7 | Compression 4.5-8-10-12-PC3 | 7.14E-06 | 0.044476 | 0.04772885 | 2 | 6,682 | 6,226 |
| 8 | Tension 4.5-14-LT1 | 0.000327 | 0.07049 | 0.362300619 | 6 | 1,107 | 216 |
| 9 | Tension 4.5-10-12-LT2 | 1.69E-07 | 0.038257 | 2.989990388 | 79 | 17,709,0 36 | 226,588 |
| 10 | Tension 4.5-8-10-12-LT3 | 3.32E-08 | 0.000337 | 0.006740563 | 21 | 203,139 | 10,151 |
| 11 | Tension 4.5-10-12-PT2 | 1.16E-05 | 0.032748 | 0.061978922 | 2 | 5,356 | 2,830 |
| 12 | Tension 4.5-8-10-12-PT3 | 2.28E-06 | 0.001055 | 0.000631666 | 1 | 277 | 463 |

Check Our Website to Use Our ML Model

Predict Deflection Via Machine Learning



This app uses machine learning to predict deflections from the given loads. Your data needs to be an excel file with load being a column in the file as show in this template.

If your data has only loads, our model will provide you back with the corresponding deflection predictions.

If your data has deflections from the field as well, our model will produce the predictions as well as some performance results to show how reliable/un is the model. In order to do this please tick the check mark below.

For any questions and/or special model and data requests contact us

Excel File



Data Has Labels ③

 \bigcap

Browse files



Future Work

- > Publish the website
- > Collect more data
- > Build a larger ML model that takes more than just the load to consider
 - Test type
 - Soil
 - Number of Plates
 - Plate size
 - And more
- > Feel free to share with us if our models can help with any existing problems or if you would like us to help build a model for your dataset

Q & A + Thank You

Tremendous Thank You To The Following People:

- 1. Our wives
- 2. Dr. Rogers (Andre's Doctoral Advisor)
- 3. Dr. Perko w/MAGNUM Piering
- 4. CTL Thompson & Helical Manufacturers for raw data

Any questions?