

# **Pennsylvania's Experience with LRFD Implementation**

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# Overview

- **Case History – Spread Footing Width and Braking force**
  - Approach from Structural Point of View
  - Parametric Study Performed
  - Abutment on Soil
  - Abutment on Rock
- **PennDOT LRFD Implementation**
  - Structure Types Implemented
  - Strategy of Implementation
  - Timeline for Implementation
  - Status
  - Schedule
  - Challenges

# Case History

- Effects of LRFD Braking Force on Foundations

- Braking force changed from LFD

- Braking force for long structures decreased w/LRFD
- Braking force for short structures increased w/LRFD

LFD: 5% of live load in all lanes carrying traffic  
(lane load plus concentrated load)

LRFD: 25% of axle weight of design truck in  
design lanes

# Case History

- ABLRFD User had noticed a large increase in footing thickness/width from LFD
- Complaints of larger footing sizes in conjunction with the LRFD specification are not uncommon
- Examined design to determine rationale for increase in footing width
- LRFD Braking Force increase resulted in change in footing size

# Case History

- Parametric Study Performed
- Looked at 5 loading Configurations
  - Original DL and LL
  - DL and LL reduced by  $\frac{1}{2}$
  - DL and LL doubled.
  - DL reduced by half; original LL
  - LL reduced by half, original DL

## Case History

- Braking Forces Varied from 0.5 kip to 2.0 kips for each Type of Loading
- Two different Abutment “types” analyzed-
  - Type 1 = 10' to 20'
  - Type 2 = 22' to 30'

# Case History

- Parameters Considered in Analysis
  - Footing Width
  - Toe Width
  - Toe Reinforcement
  - Heel Width
  - Heel Reinforcement
  - Stem Reinforcement

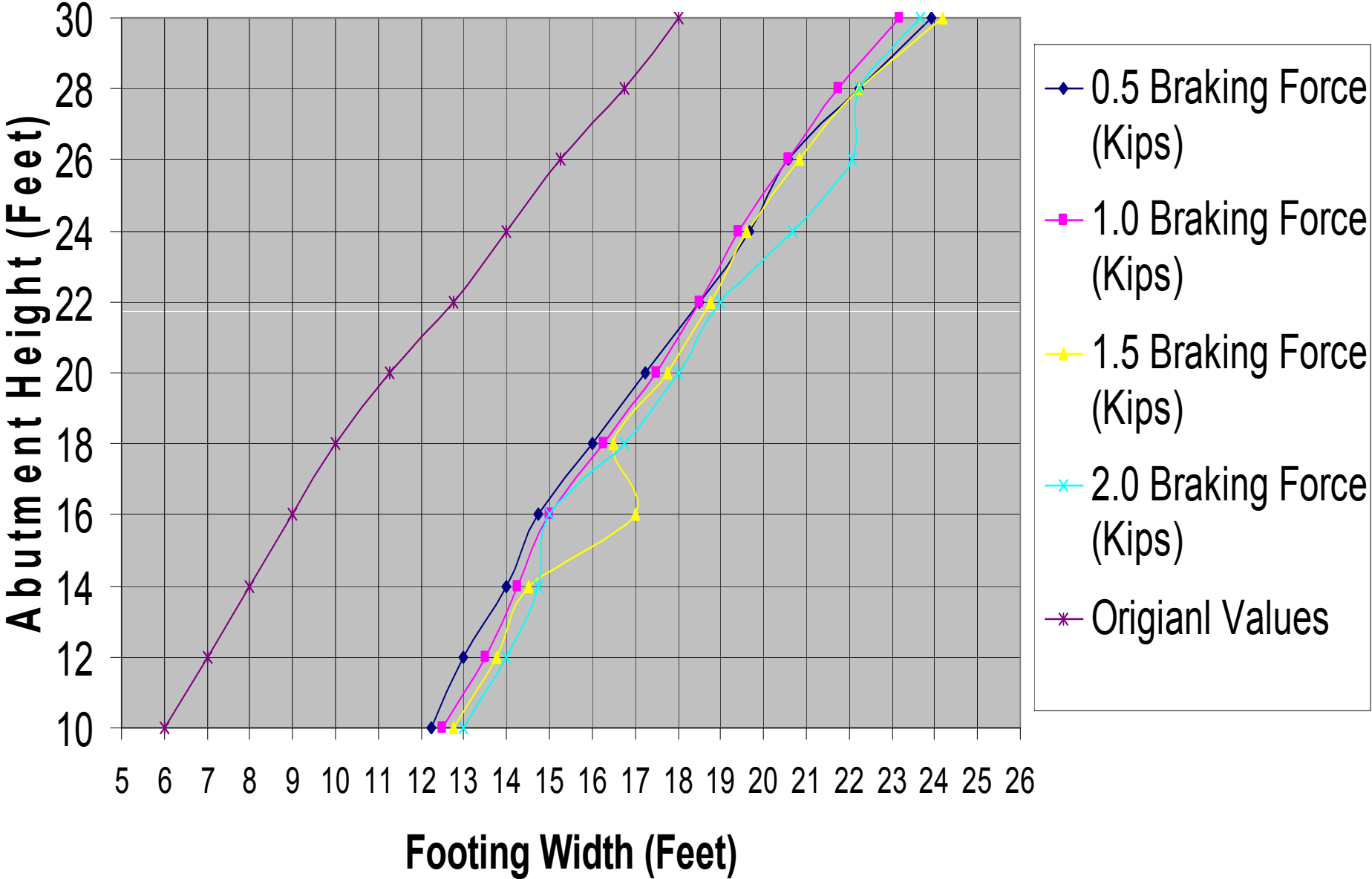
# Reinforced Concrete Abutment

Spread Footing On Soil

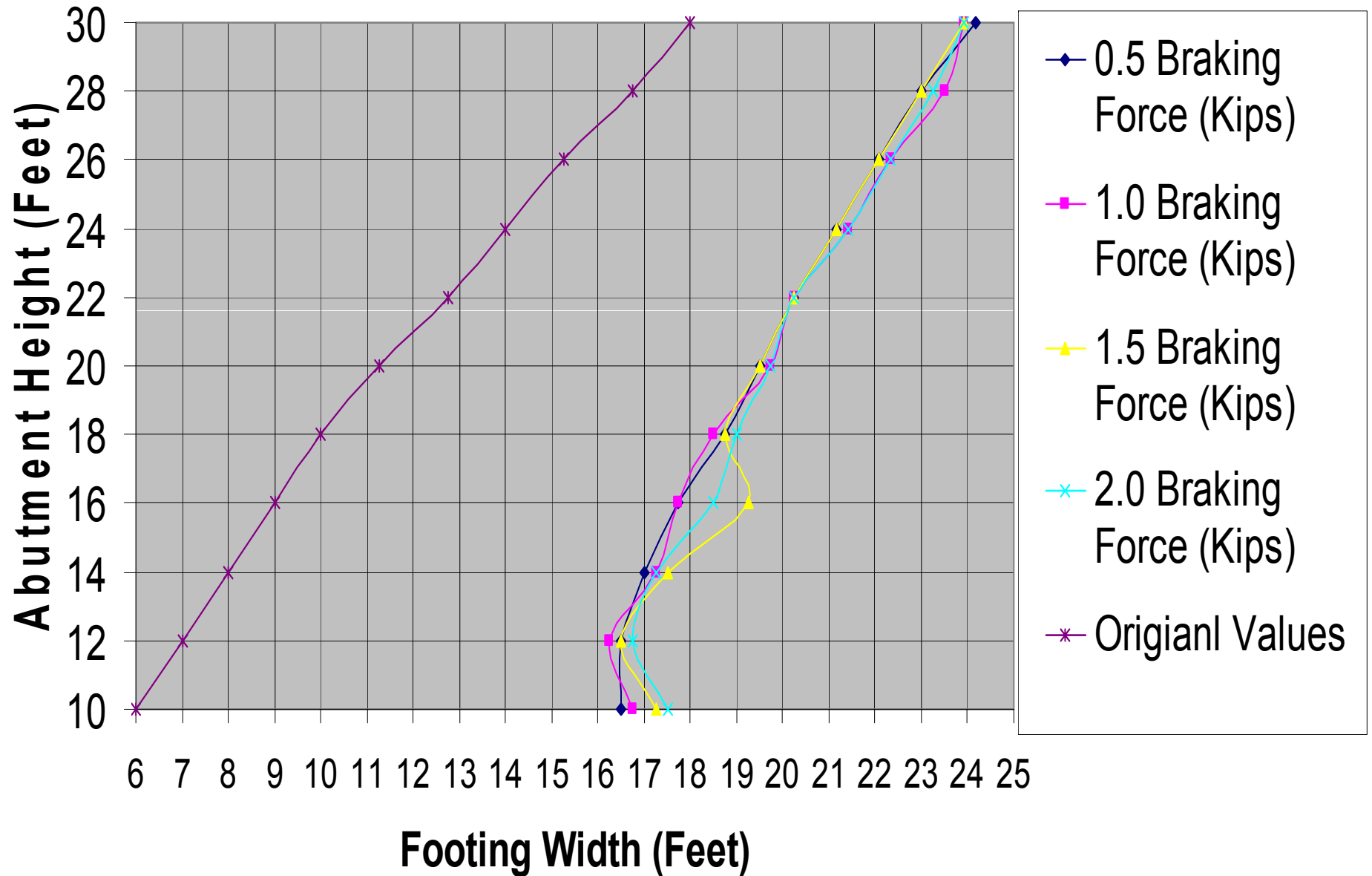




R.C Abutment, Original Values. Spread Footing on Soil.



R.C Abutment, DL and LL Doubled. Spread Footing on Soil.

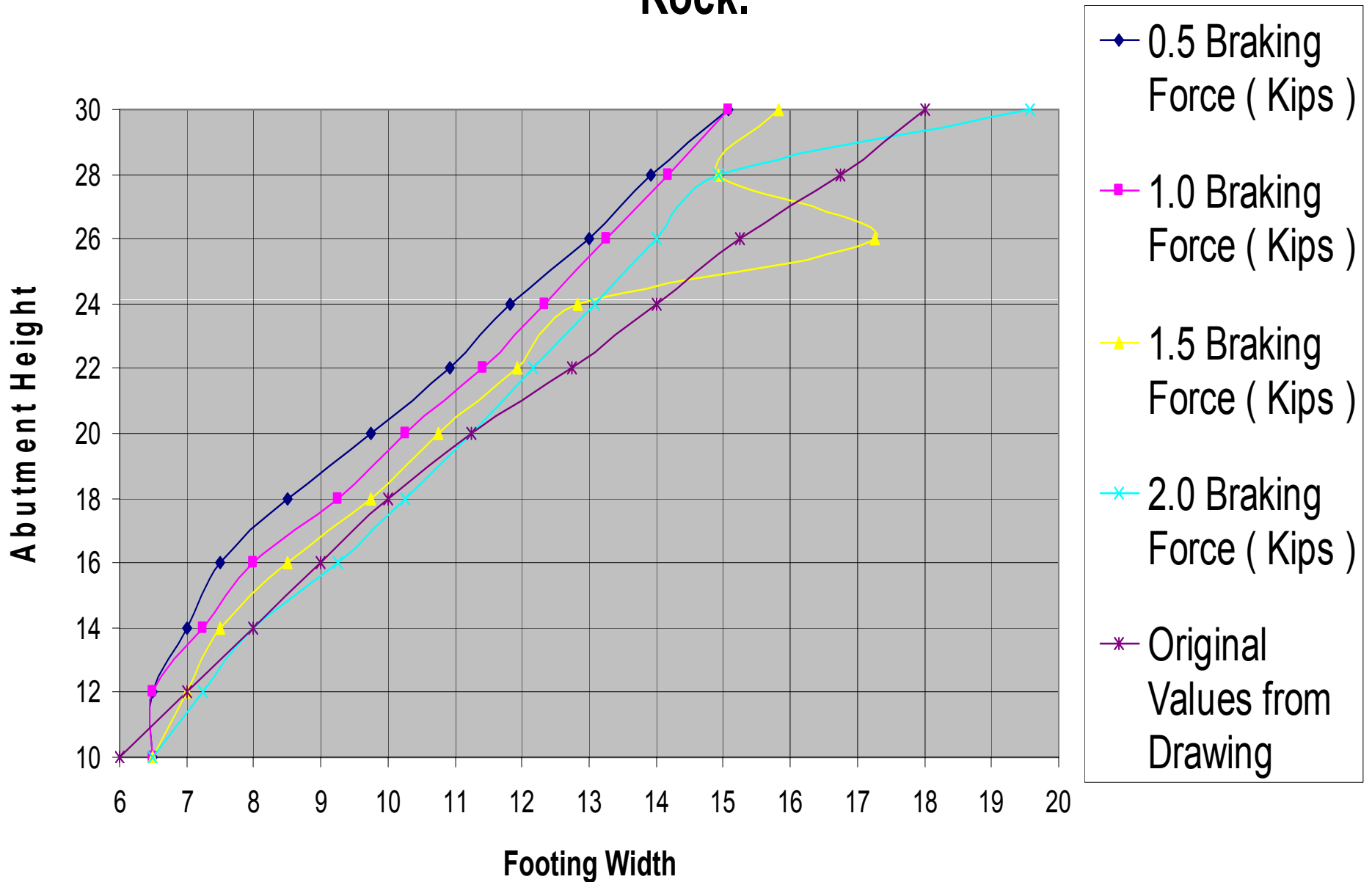


# Reinforced Concrete Abutment

Spread Footing on  
Rock

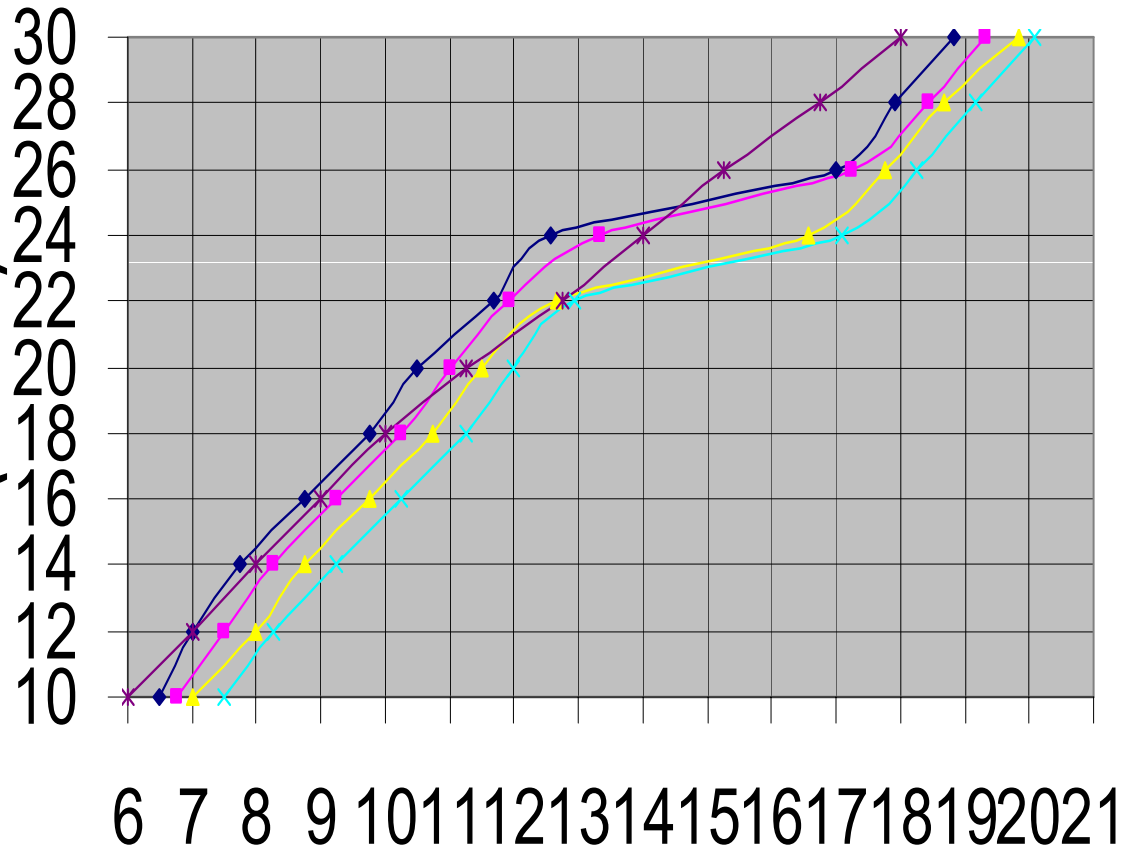


# R.C. Abutment, Original Values. Spread Footing on Rock.



## R.C Abutment, DL and LL Reduced by Half. Spread Footing on Rock.

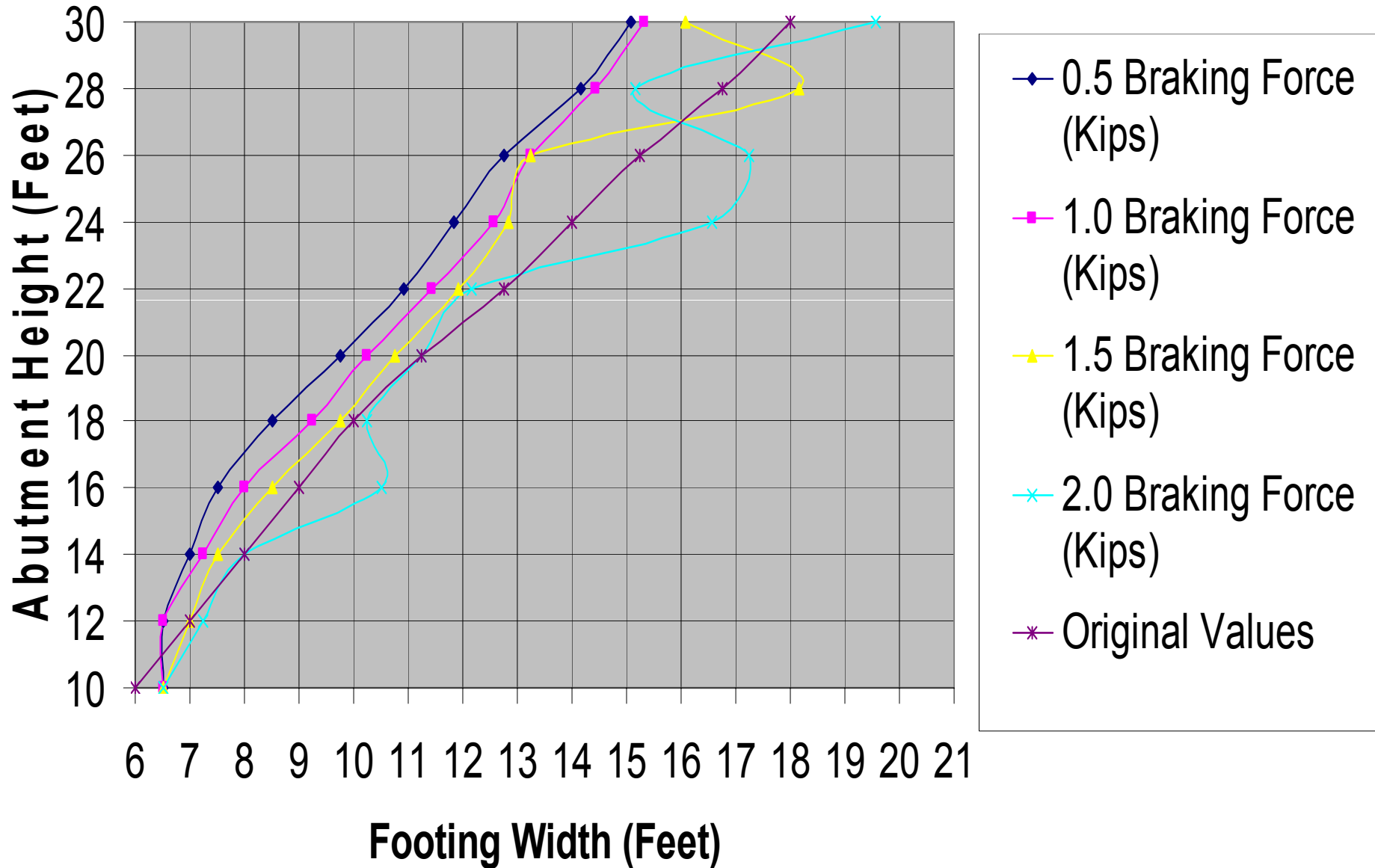
Abutment Height  
(Feet)



Footing Width (Feet)

- 0.5 Braking Force (Kips)
- 1.0 Braking Force (Kips)
- 1.5 Braking Force (Kips)
- 2.0 Braking Force (Kips)
- Original Values from Drawing.

R.C Abutment, LL Reduced by Half and Original LL.



## Case History

- Summary & Conclusions:

For spread footings on soil, footing width increased dramatically with the braking force change.

Footing width did increase with increased DL and LL, as expected, but did not vary to the extent of the braking force influence.

# Case History

- Adjustments to practice:
  - Verbiage in PennDOT’s design manual warning increase in braking force effects for short spans (i.e. greater than LFD for short spans <500’).
  - “Braking Force Factors” specified for longer structures to bring practice more in line with LFD forces
  - Equivalent load factor included in Abutment and Retaining Wall program output





# **LRFD Implementation**



# LRFD Implementation

- PennDOT has implemented LRFD for :
  - Piles
  - Caissons
  - Micropiles
  - Spread Footings
  - MSE Walls
  - Retaining Walls – cantilever, soldier pile, etc.

# LRFD Implementation – Strategy of Implementation

- Strategy of Implementation
  - Modify LRFD specification to be in relative agreement with LFD practices, or thoroughly understand implications of LRFD changes before accepting them.
  - Develop LRFD Computer programs
  - Implement Metric Concurrently
  - Hold training sessions:
    - Inform designers of LRFD specification changes
    - Specific to LRFD computer programs

# LRFD Implementation – Strategy of Implementation

- Sample Modifications to AASHTO
  - Shallow Foundations – Differences from AASHTO
    - Bearing Capacity Clay  $\Phi = 0.55$  (vs. 0.6) for Rational Method
    - Rock Semi-empirical  $\Phi = 0.55$  vs. 0.6
    - Overall Stability  $\Phi = 0.85$  vs. 0.90
    - No presumptive values permitted
    - Use AASHTO 10.6.3.2.2 for Semi Empirical procedure
  - Pile Foundations – Differences from AASHTO
    - $\lambda$  not considered for Ultimate Bearing Resistance of piles
    - 0.50 for Wave Equation Analysis vs. 0.40

# LRFD Implementation - Status

- Timeline for Implementation:
  - 1993/94 – Begin Task Force Work; LRFD Specifications
  - LRFD Training Sessions Begin in 1994
    - Superstructures First
    - Followed by LRFD substructures
    - LRFD computer programs
    - Ongoing training sessions for computer programs
  - 1997 - LRFD Programs Available:
    - PSLRFD – Prestressed Beams
    - STLRFD – Steel Beams
    - BPLRFD – Bearing Pad

# LRFD Implementation - Status

- Time Line (cont.):
  - 1998 – LRFD Abutment and Retaining Wall Program Available
    - Adopted 1996 LRFD AASHTO
  - 2001 - PAPier, LRFD Pier Program
    - Adopt 1998 LRFD AASHTO
  - 2007 Adopt 2004 LRFD AASHTO  
(2006 AASHTO Interim for foundations)

# Status of Implementation

- Bridges: Completely Implemented
- Retaining Walls: Completely implemented
  - LRFD Program available for CIP cantilever retaining walls, gravity walls
  - LRFD design required for soldier pile walls, etc.
- Schedule:
  - Begin Implementation 1995 with LRFD for superstructure; LFD for substructure
  - End/Full Implementation in 2001

# Implementation – Challenges in LRFD

- Challenges in LRFD Design:
  - Identify factors / LRFD provisions affecting footing size
    - Complaints of larger foundations using LRFD; difficult to pinpoint reasons
    - Ongoing investigations into cause(s) of increase
  - Proper interpretation of the specification
    - Inclination factors
    - Determination of  $N_{ms}$  coefficient for Estimation of Ultimate bearing capacity



# Implementation – Challenges in LRFD

- **Proper interpretation of the specification (cont.)**
  - EH-V – initially applied EH-V incorrectly (conservative)
  - ES – program users used the same as EV
  - Down drag
    - With LFD found loads to be large and result in conservative and costly designs
    - Use of “minimum” 0.45 only with LRFD
    - Use of 1.80 maximum overly conservative
- **Implementing LRFD for Proprietary Products/Structures**

# Implementation – Challenges in LRFD: Construction

- Construction:
  - Construction Submittals for Temporary Shoring to be LRFD
  - Interpretation of the LRFD Spec. in the field
    - Dynamic Pile Monitoring & Load Tests – change from Factor of Safety to use of resistance factors
    - Limited exposure of construction personnel to concepts for LRFD/LRFD design

# Summary & Conclusion

- **Challenges**

- Understanding implications of LFD to LRFD specification changes
- Proper implementation of LRFD specs.
- Need for educating both Design and Construction Sides
- Working with proprietary products to implement LRFD design

- **Lessons learned** – can't anticipate all effects of the changes to the LRFD specifications; ongoing learning curve

- **Adjustments to practice** - Ongoing