
Characterization of the Biomechanical Response of Racing Surfaces

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Knowledge to Go Places

Outline

- Objectives
- What hoof sees
- The ground reaction
- Experimental Approach
- Apparatus



Objective:

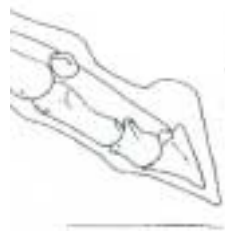
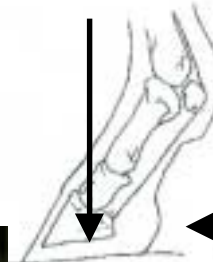
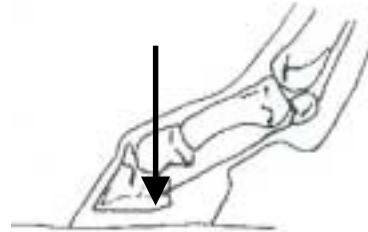
Load the Track like a Horse

- Design tests for evaluating tracks
- Determine the correct loads and speeds to match racing
- Build apparatus to perform tests
- Develop numbers for initial test tracks which can be compared between days



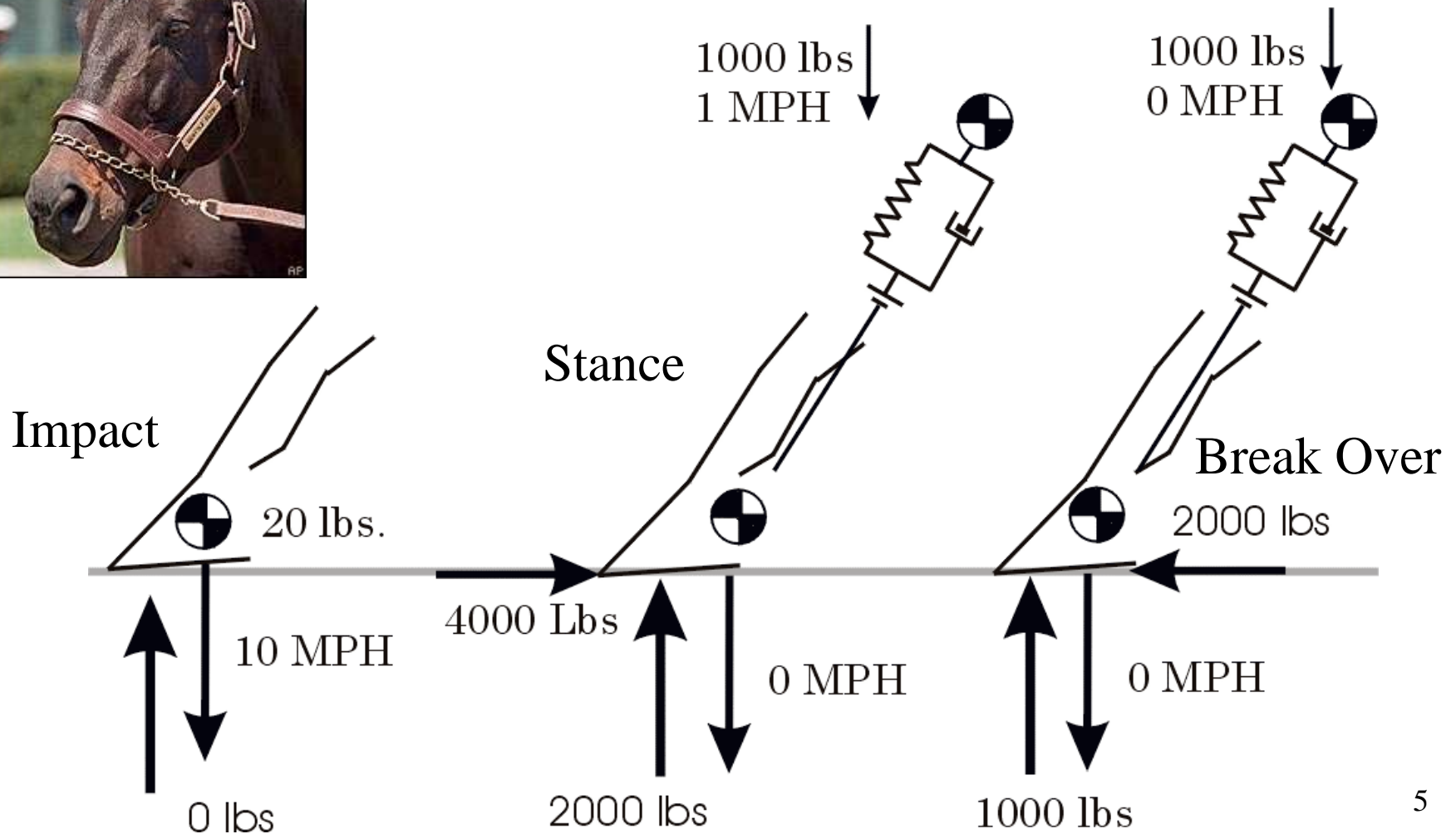
Phases of Gait

- Impact
 - Vertical Loading Joint Impact
- Stance phase
 - Vertical loading of soil/shear
- Break-Over
 - Unloading with shear
- Swing





Loading of Hoof

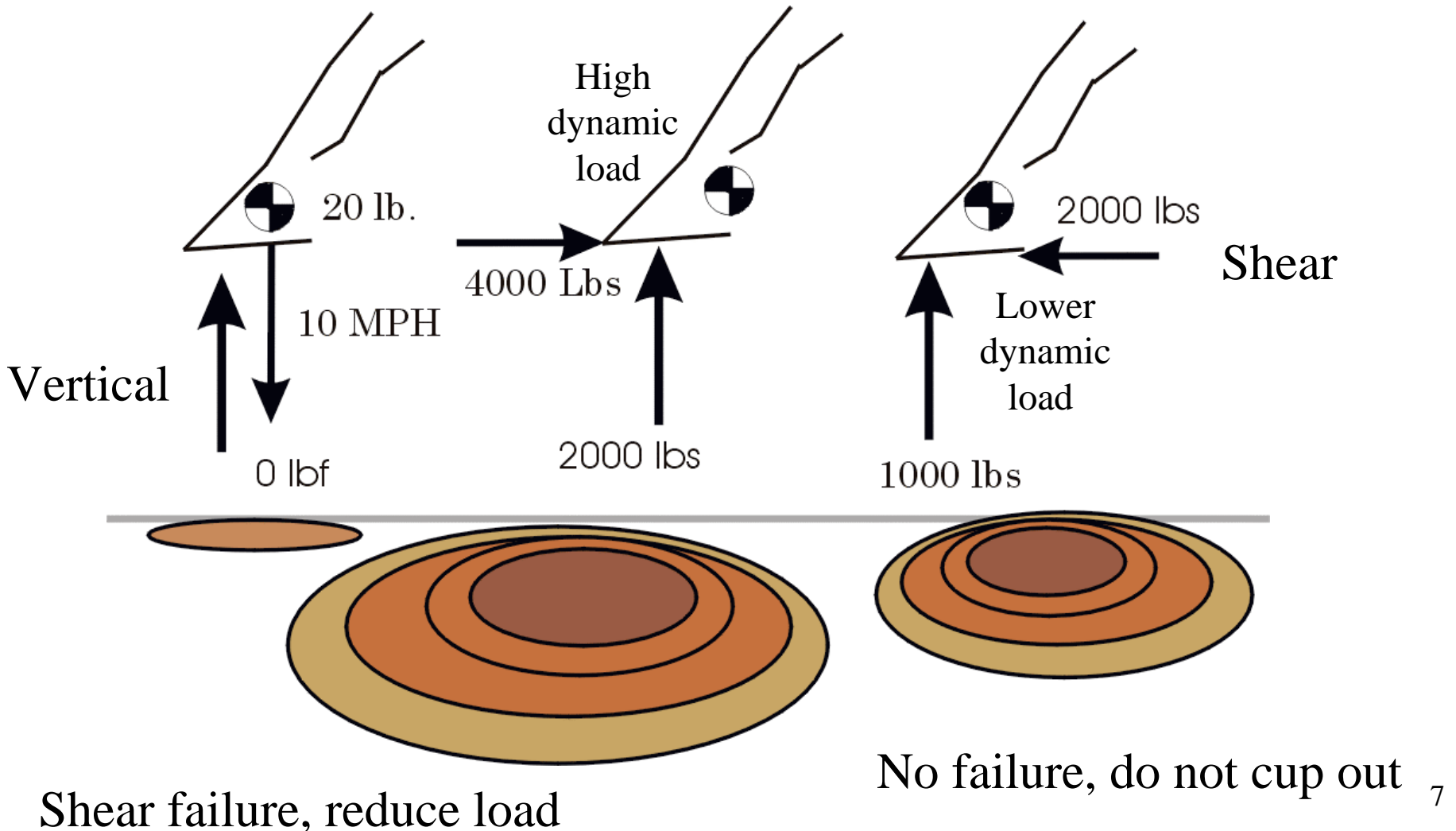


What The Hoof Sees..

- Impact \Rightarrow How stiff vertically
 - High speed – 10 m/s
 - Low load – hoof mass
- Stance \Rightarrow How stiff vertically
 - Low Vert. Speed (hoof relative to ground)
 - High load – mass of hoof + dynamic horse
- Stance \Rightarrow Horizontal stiffness
 - High speed – deceleration of hoof
 - Very high load \Rightarrow shear failure
- Break over \Rightarrow Horizontal shear strength
 - Low Speed (hoof relative to ground)
 - High load – push off, No shear failure

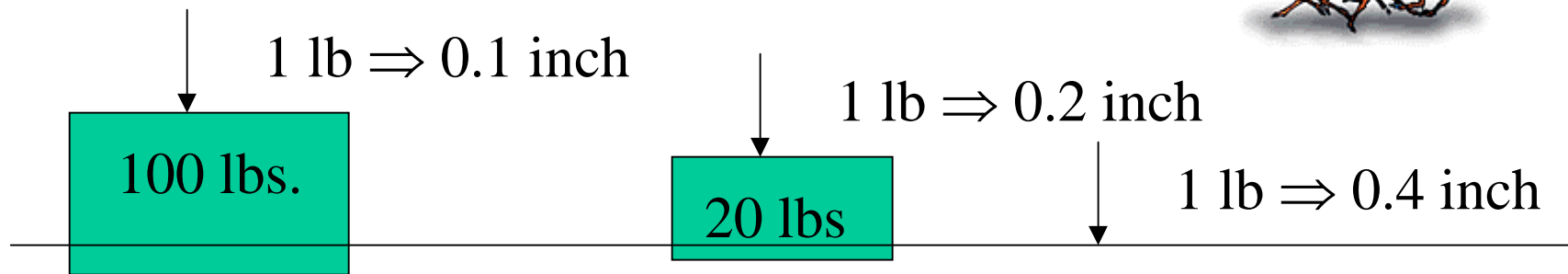


The Ground Reaction

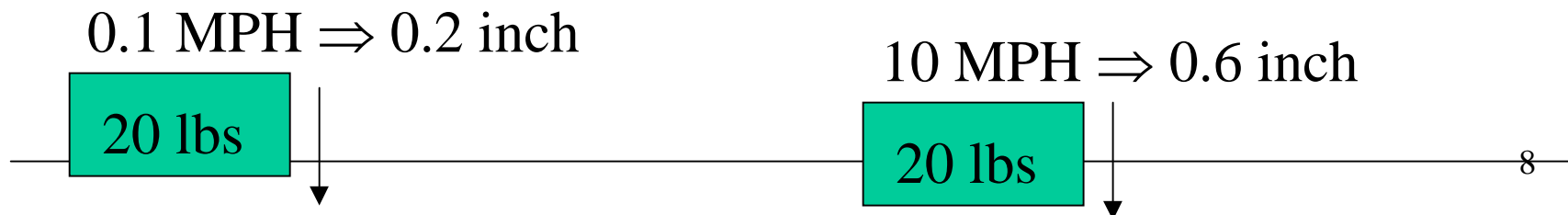


Why all this detail?

- Soil -- Non-linear
 - Stiffness depends on amount of load



- Strain rate dependent – soil behavior



Coupled Problem

- Vertical Stiffness
 - Elastic
 - vertically compresses
 - Plastic
 - Leaves a footprint
 - Non-linear
 - Stiffer as you compress
 - Rate Dependent
 - Softer if you load faster
 - Horizontal Shear Strength
 - Depends on load
 - Rate Dependent
 - Failure below surface
- Speed and direction
- Need speed and direction of load

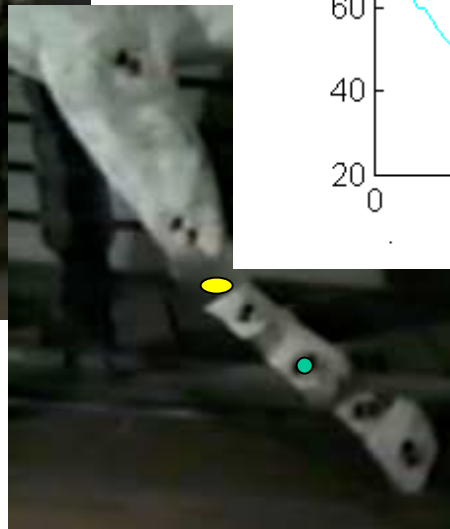
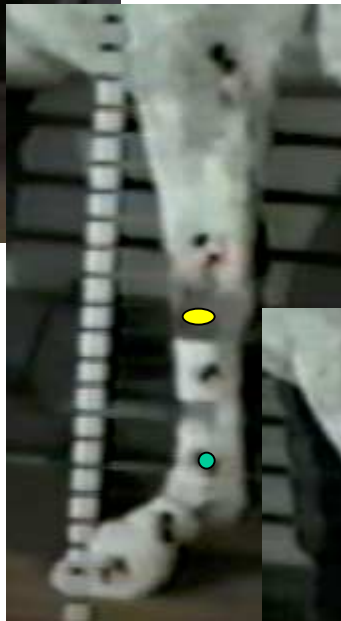


Required Tests

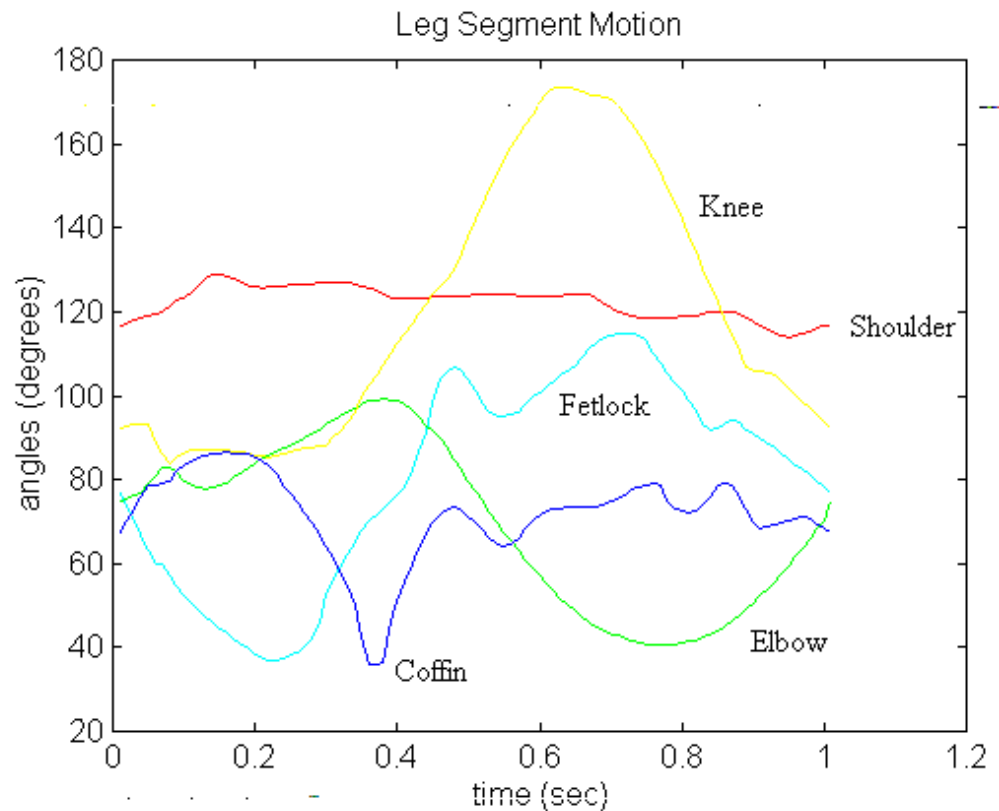
- Step 1: Measurements to design test system
 - Speed of hoof at impact – extend G. Pratt & others
 - Motion of horse & hoof
 - “Kinematics of the Gallop”
- Step 2: Soil Test Fixtures
 - Vertical testing of soil
 - Impact of hoof
 - Stance
 - Horizontal testing of soil
 - Strength of soil
 - Stiffness of soil



Step 1: Kinematics

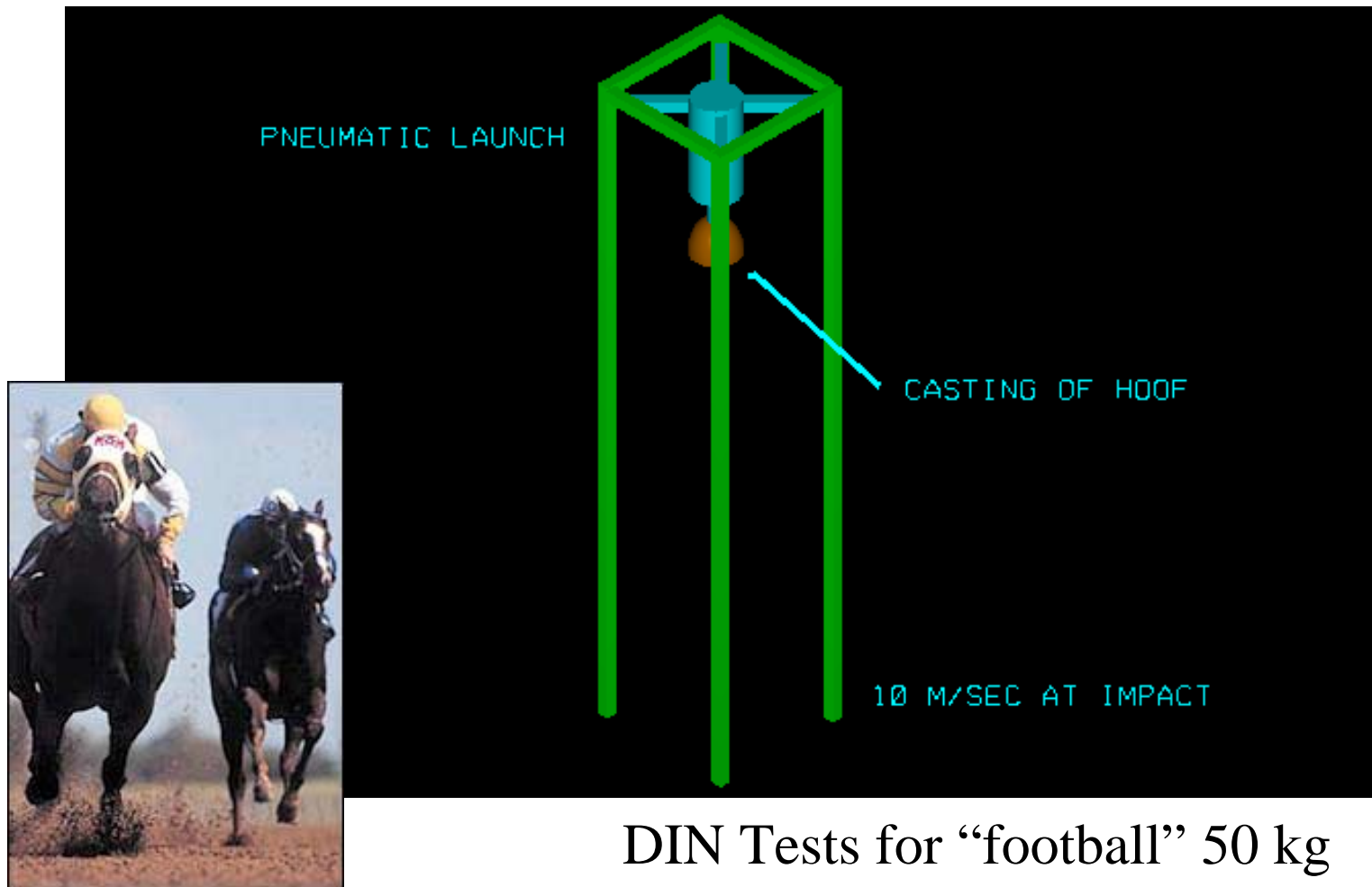


G. Pratt – horizontal
F. Frederick - vertical



Direction and speed of
hoof at ground at gallop
on track

Step 2: Vertical Load Fixture

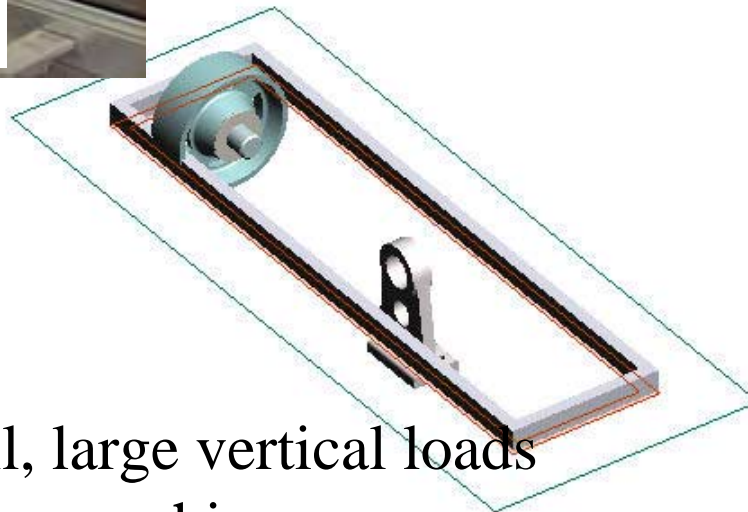


DIN Tests for “football” 50 kg
Traditional tests for horses 10 kg!

Step 2 (cont.): Horizontal Load



Horizontal Load

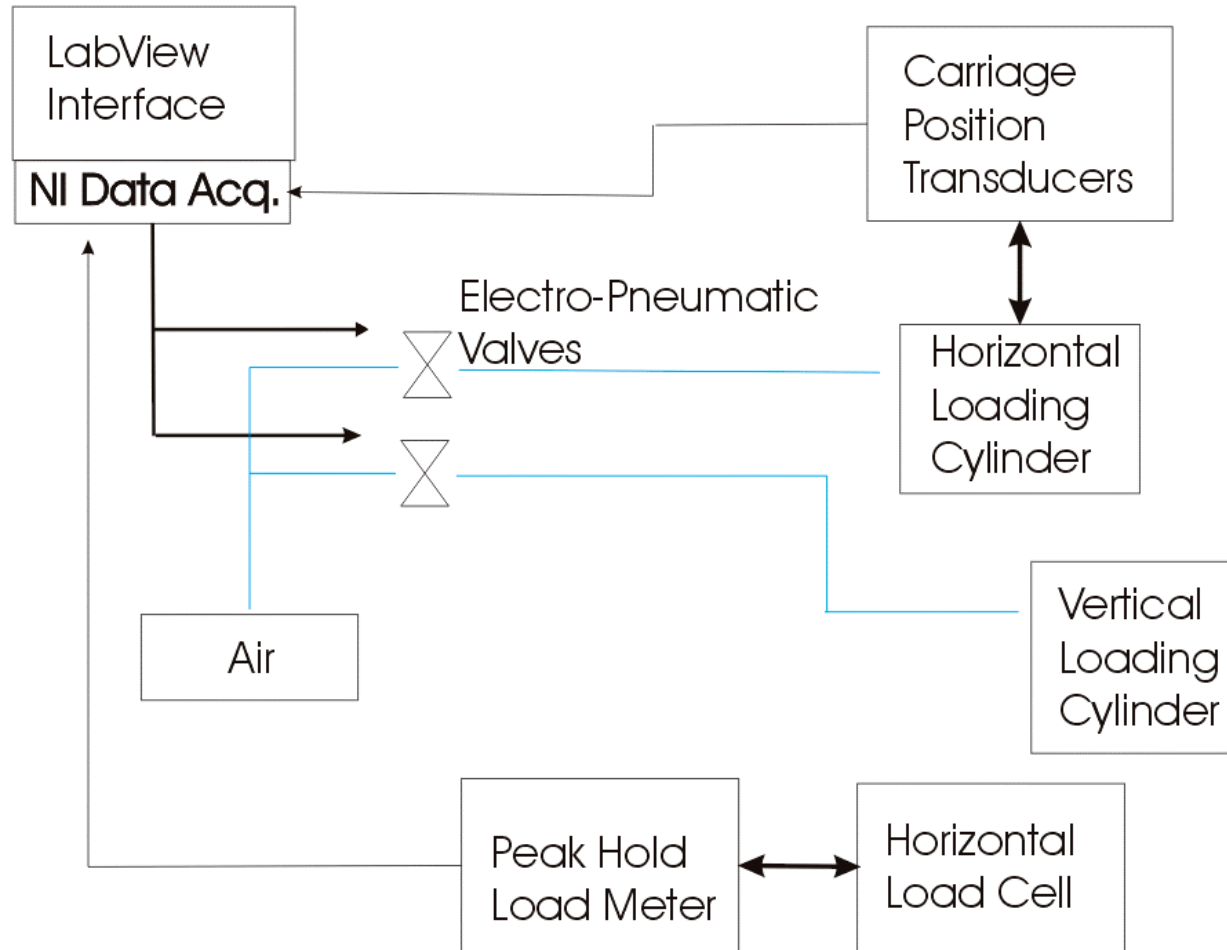


Optimize shear testing of soil, large vertical loads

Decelerate with shear cushion

Do not cup out on propulsive motion

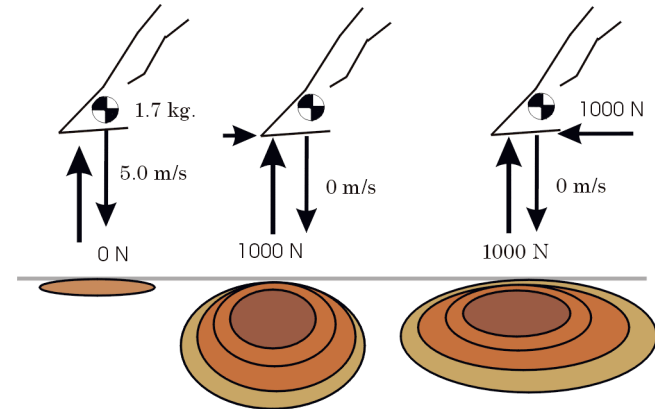
Controls of Horizontal Load



At The End of the Day....

- Adapt testing systems for use on a regular basis
 - Impact fixture – hoof at ground
 - Modified tractors
 - Shear out
 - Vertical modulus
 - Horizontal modulus
- Track managers and soil chemists
 - hold the numbers

Track Surfaces



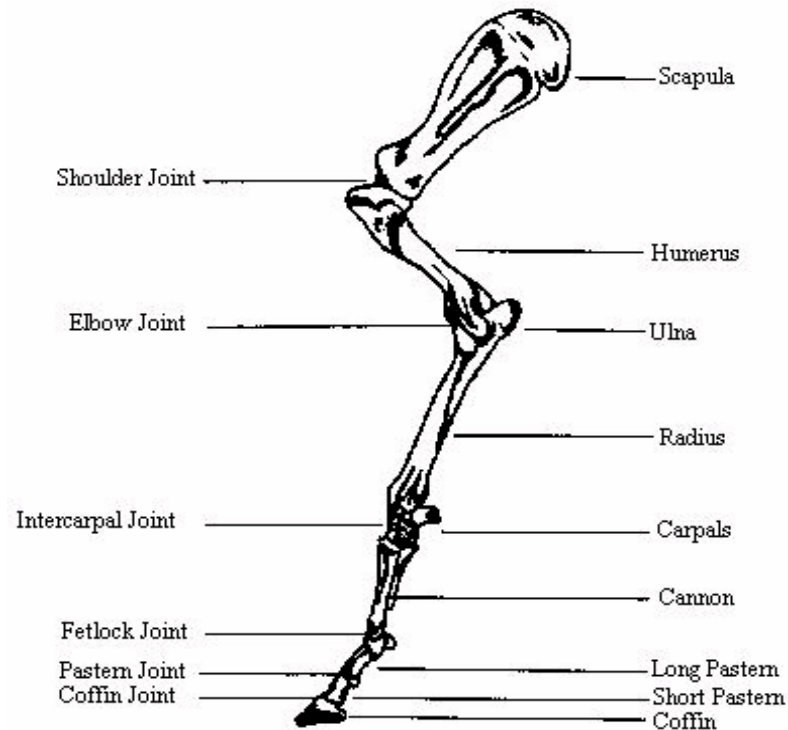
- **Strain rate dependent**
- **Non-linear load deformation response**

Translation:

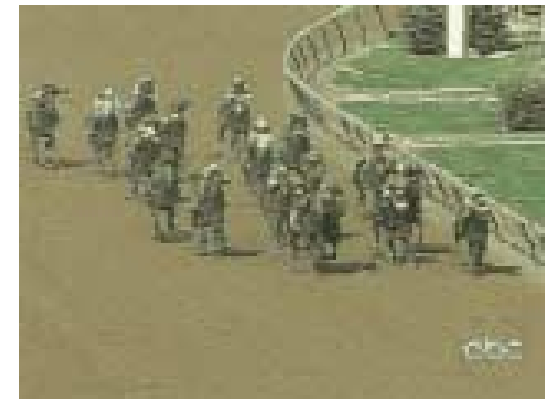
*You need to load the soil like a horse
SPEED, FORCE AND DIRECTION!!*



Discussion

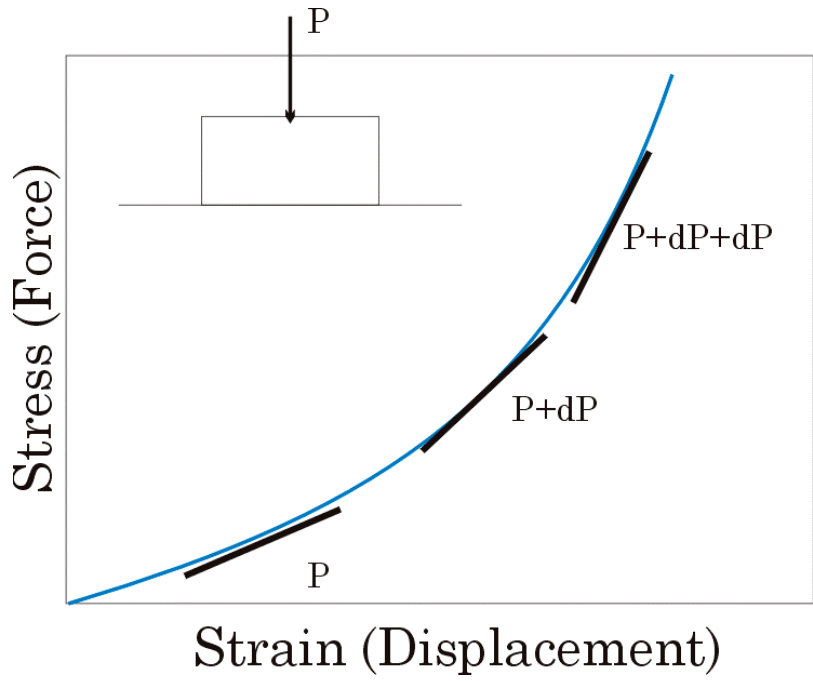


Bones and Joints of Horse's Foreleg



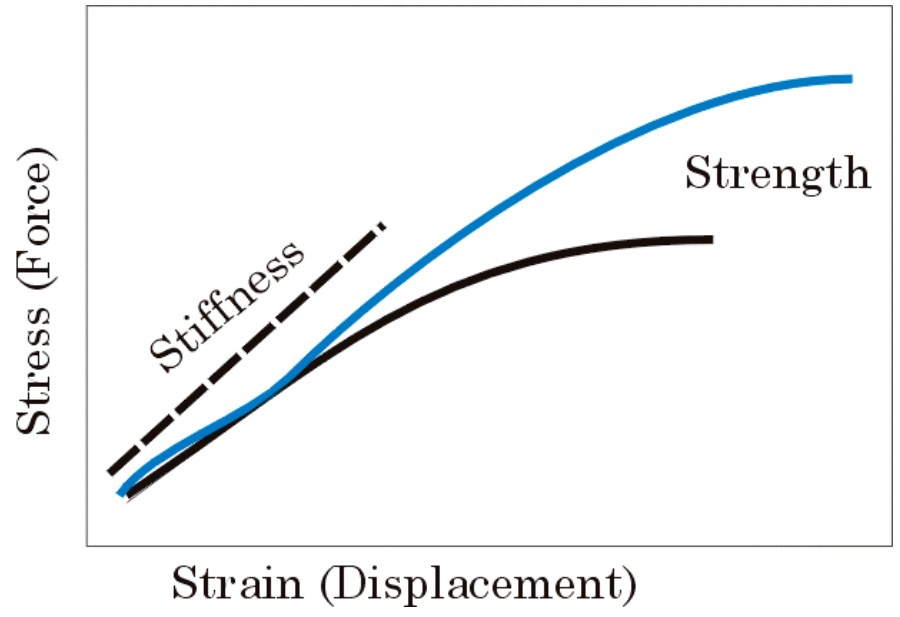
Tangent Modulus

Used in playing surface research



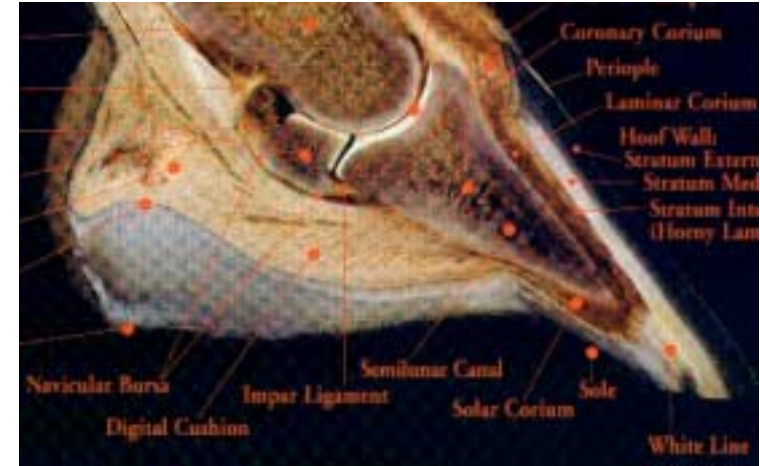
Strength vs. Stiffness

Used in playing surface research



What this will produce

- Numbers
 - Compare what you will see on a track one day with the previous day
 - Numbers can be posted
- NOT
- What “needs to be done”
- BUT
- What the hoof sees



This will not replace the track superintendent and designer..

- Tracks will still need to be constructed from local materials and managed for local weather
- Track superintendents will still need to develop procedures to maintain consistent tracks:
 - Moisture addition control
 - Addition of sand, fibers and clay content
- Will not tell how to build tracks:
 - Depth of compaction layer (hard - soft - hard)
 - Roots/fibers/grids (2 to 3 times the shear strength)



WILL KNOW THE TRACK IS GOOD OR BAD!!!

What We Know Matters

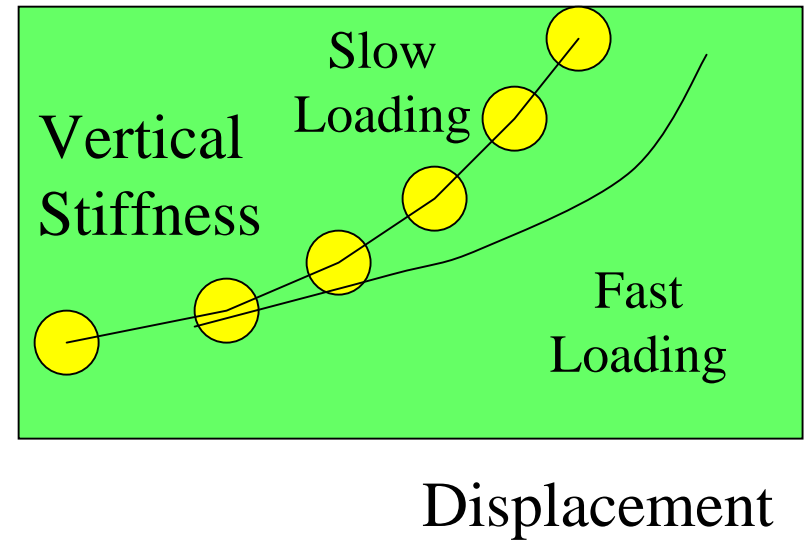
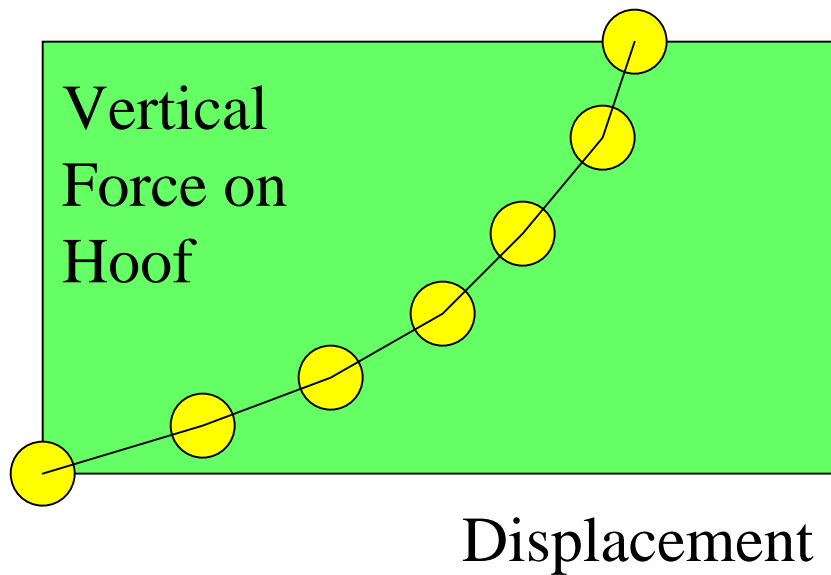
- Impact resistance of soil
 - Bulk density
 - Moisture content
 - Particle size distribution
- Shear strength
 - Depth of compaction layer (hard - soft - hard)
 - Roots (2 to 3 times the shear strength)



NEED A HOOV'S VIEW OF TRACK

Impact and Stance

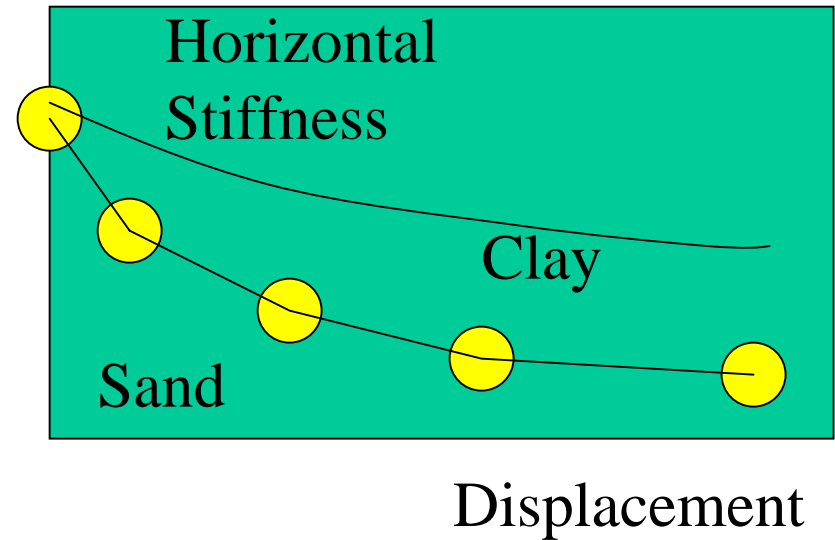
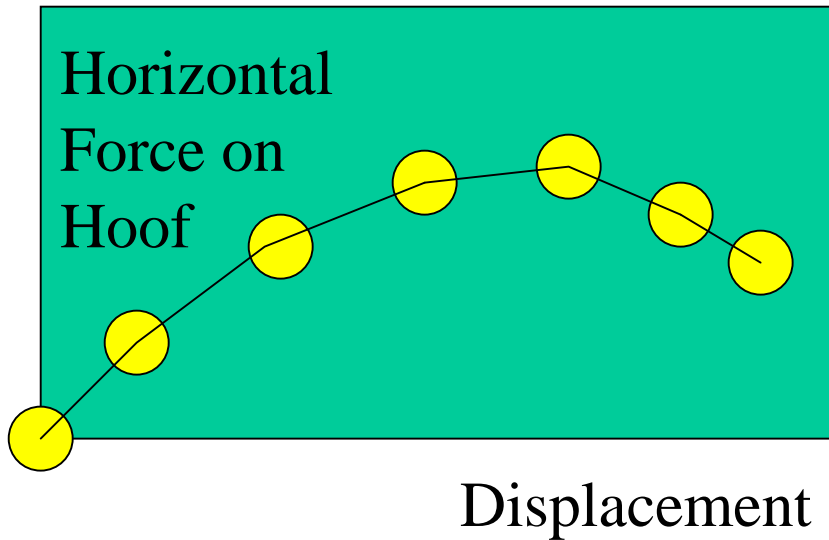
Vertical Stiffness



- Horizontal force **DECREASES** before it fails
- Soil becomes less stiff as you load it

Break Over

Horizontal Stiffness and Strength



- Horizontal force **DECREASES** before it fails
- Soil becomes less stiff as you load it

Related Non-Equine Work

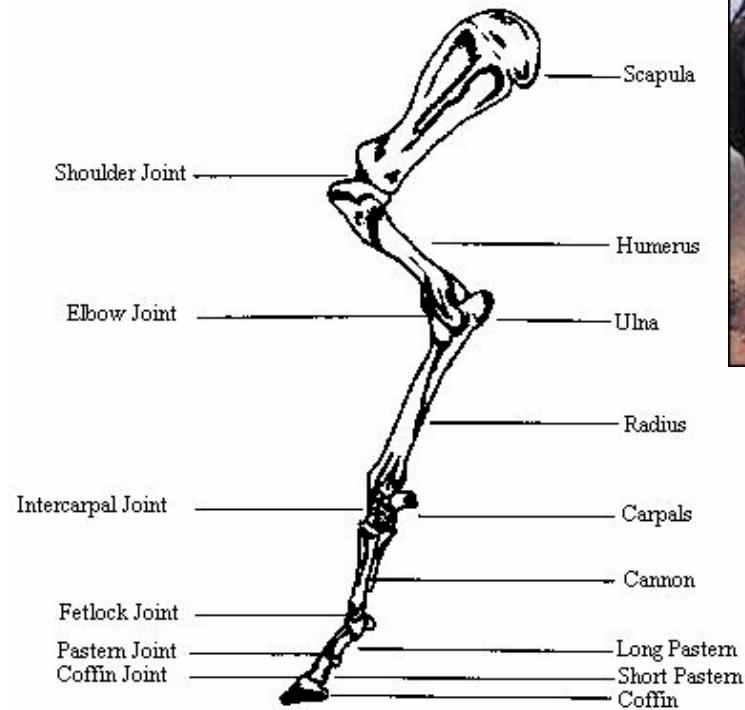
- Soil and traction
 - Terramechanics
 - Tractors
 - Tanks
 - Robotics
 - Mars rover
 - Legged robots -- terrestrial navigation
 - Soil mechanics
 - Penetration for high rate impact
- Biomechanics
 - Sports surfaces
 - Kinematics from equine studies



Report of Congress on the Defeat of Hard and Deeply Buried Targets
www.nukewatch.org/important_documents.html#hdbt

Future Work

- Kinematic modeling (what injures the horse!)
- FEA modeling of soil
- Consider soil “design” - fiber like roots in turf



Bones and Joints of Horse's Foreleg



Extensions -- Additional Support

- Occupational Safety and Health
- Turf surfaces for sports injuries
- Shoes for trail running
- Off-road tire design

