

# Getting it Right - Downdrag and LRFD

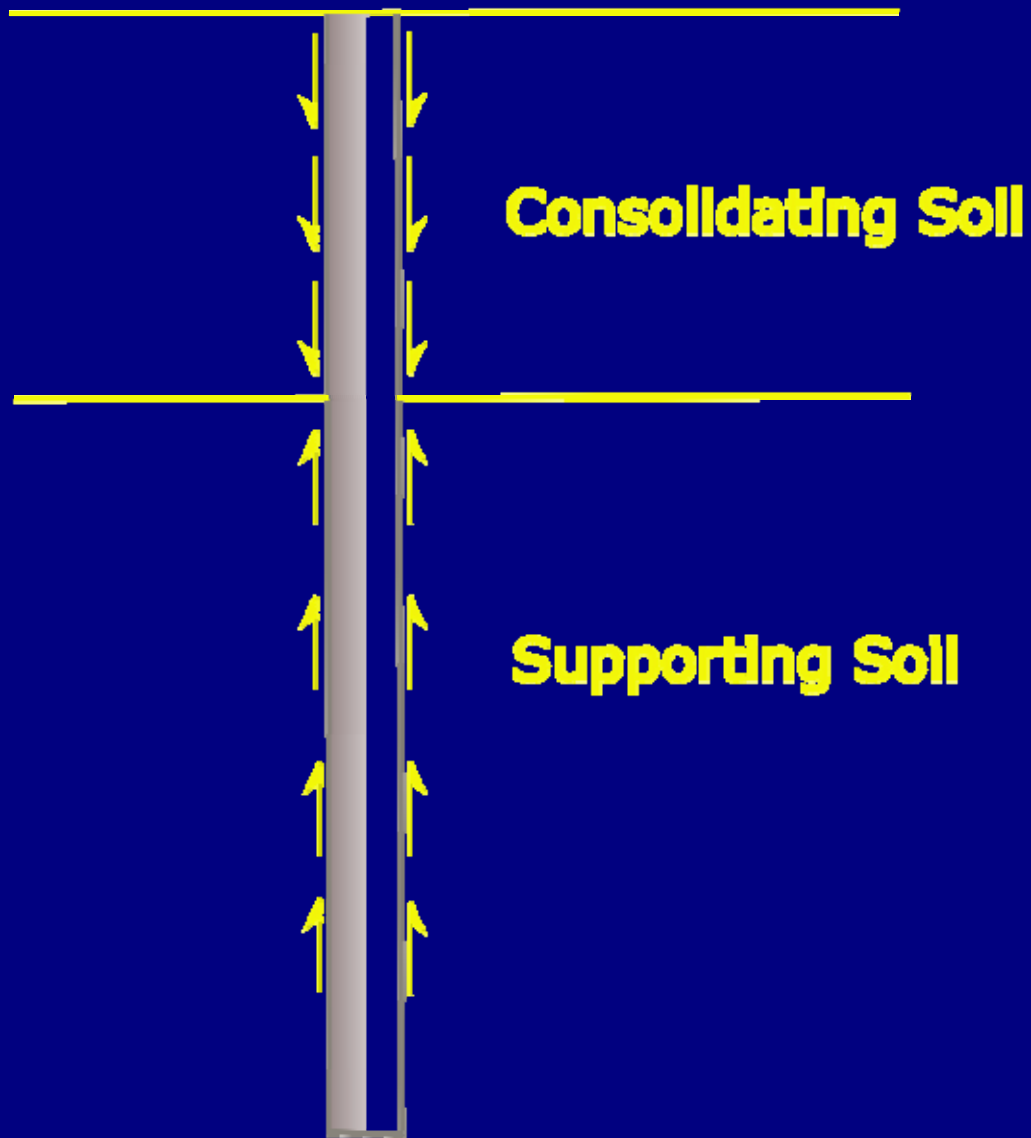


Stuart Edwards, P.E.

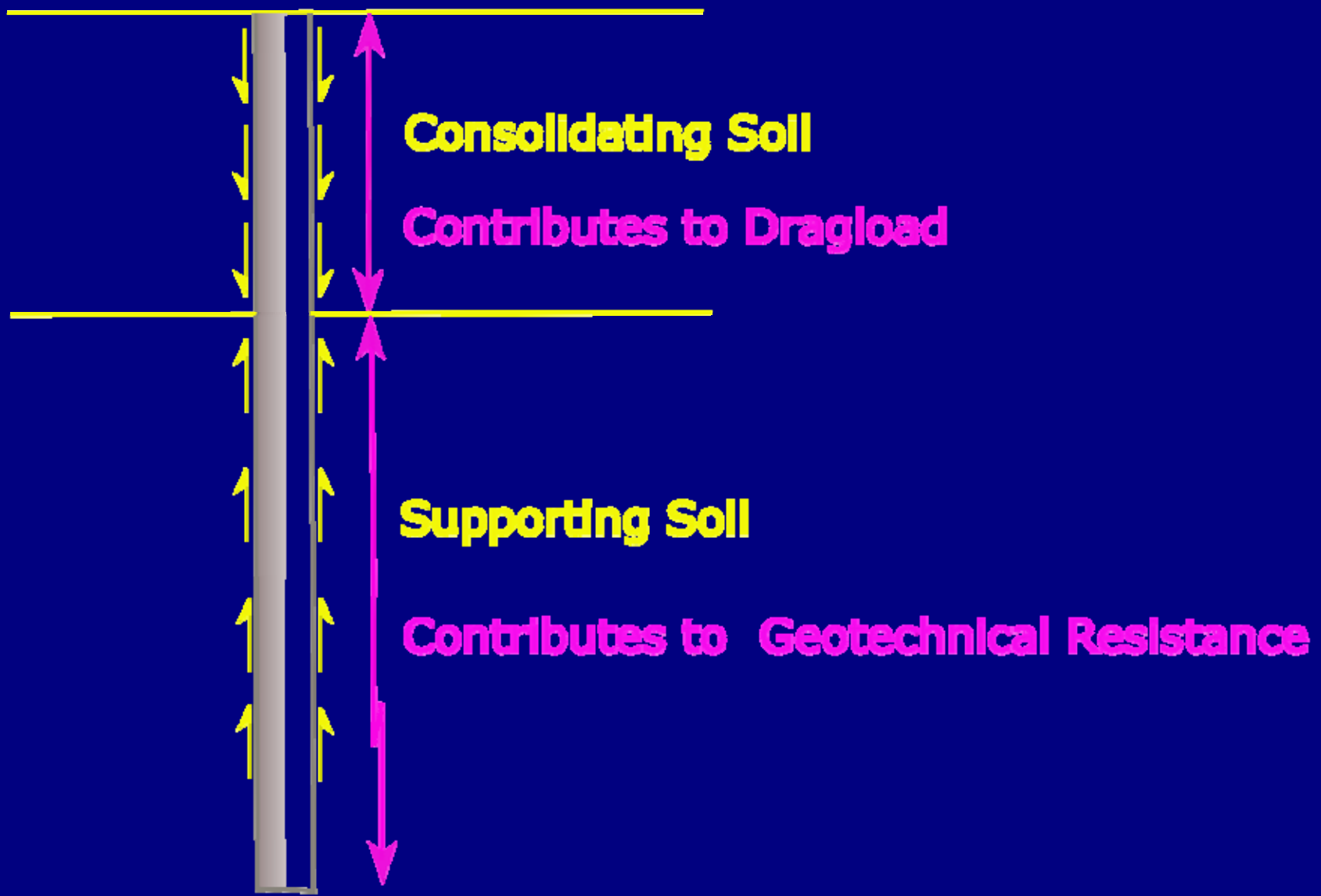
Is the current Design Specification approach to Downdrag too conservative, and if so, what are the ramifications – and is there a solution?

- Classical Downdrag
- Case History
- NeoDowndrag
- Case History (2)
- Suggestions

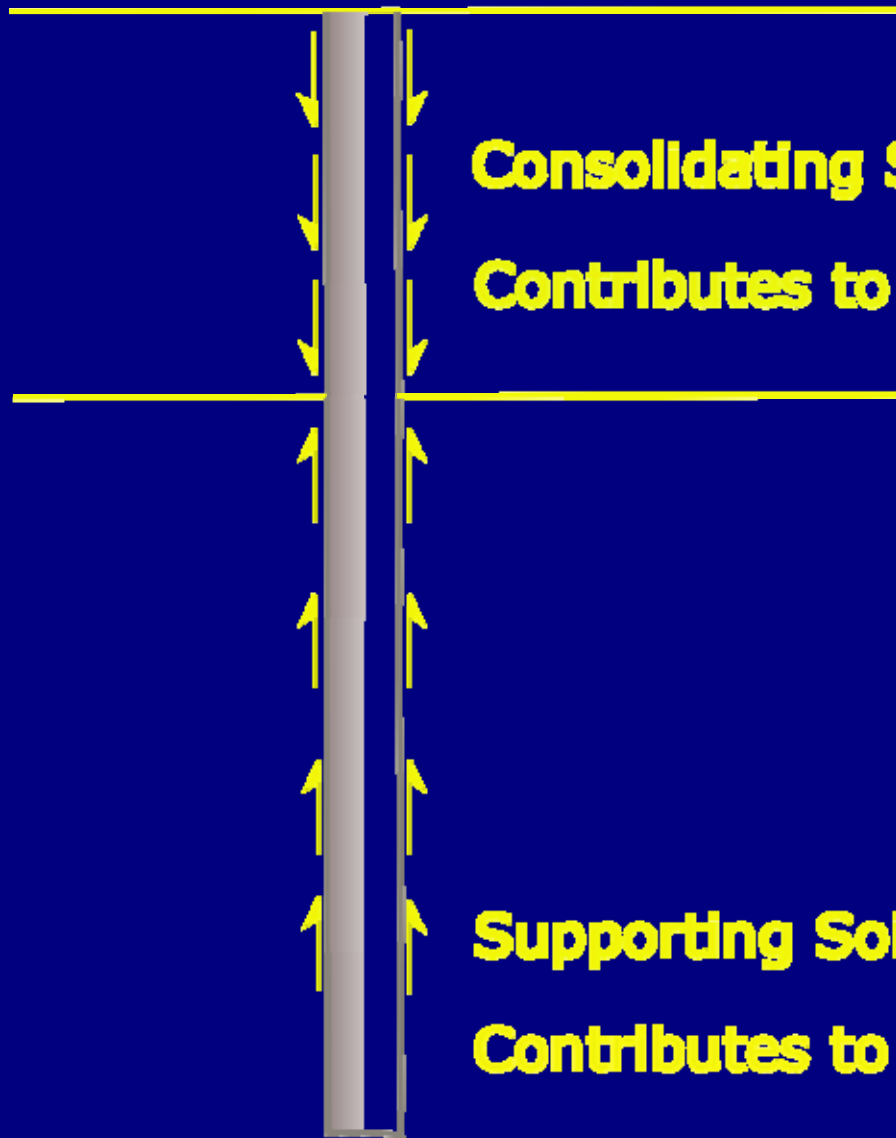
# Classical Downdrag (DD)



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**Consolidating Soil**

**Contributes to Dragload**

**Dragload aka Downdrag:**

**a) Offers no support**

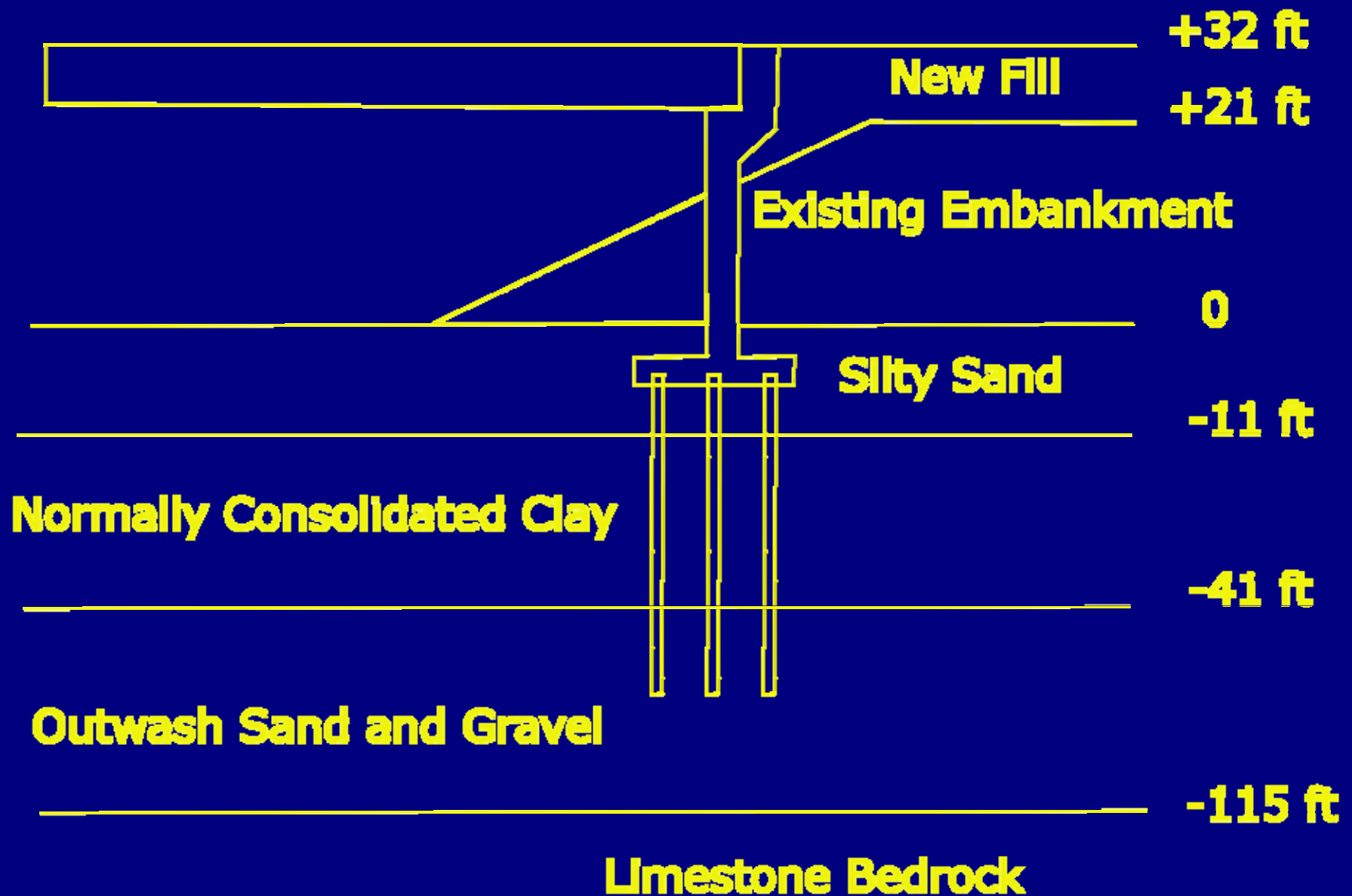
**b) Must be treated as a load to be resisted**

**Supporting Soil**

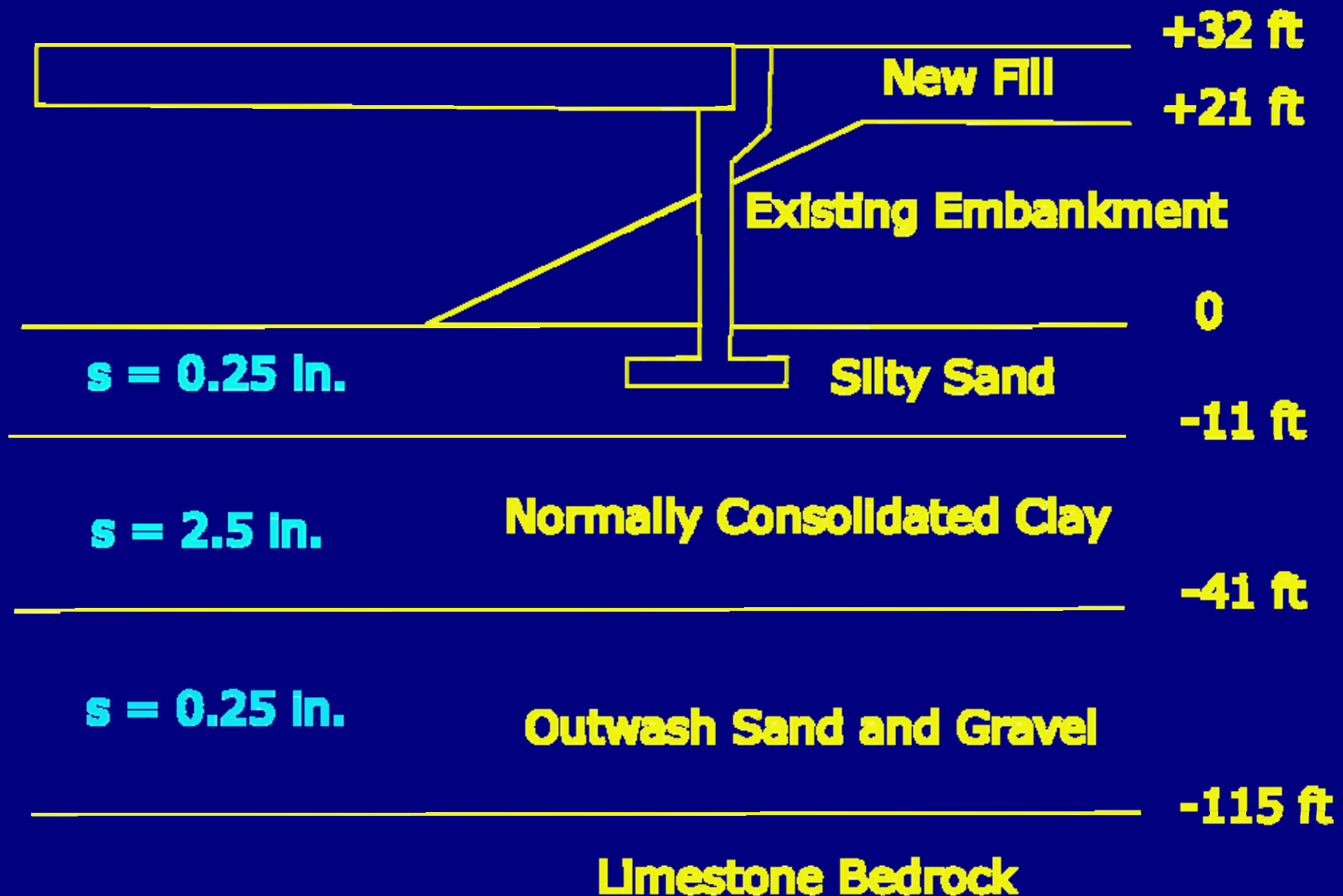
**Contributes to Geotechnical Resistance**

# Case History (1)

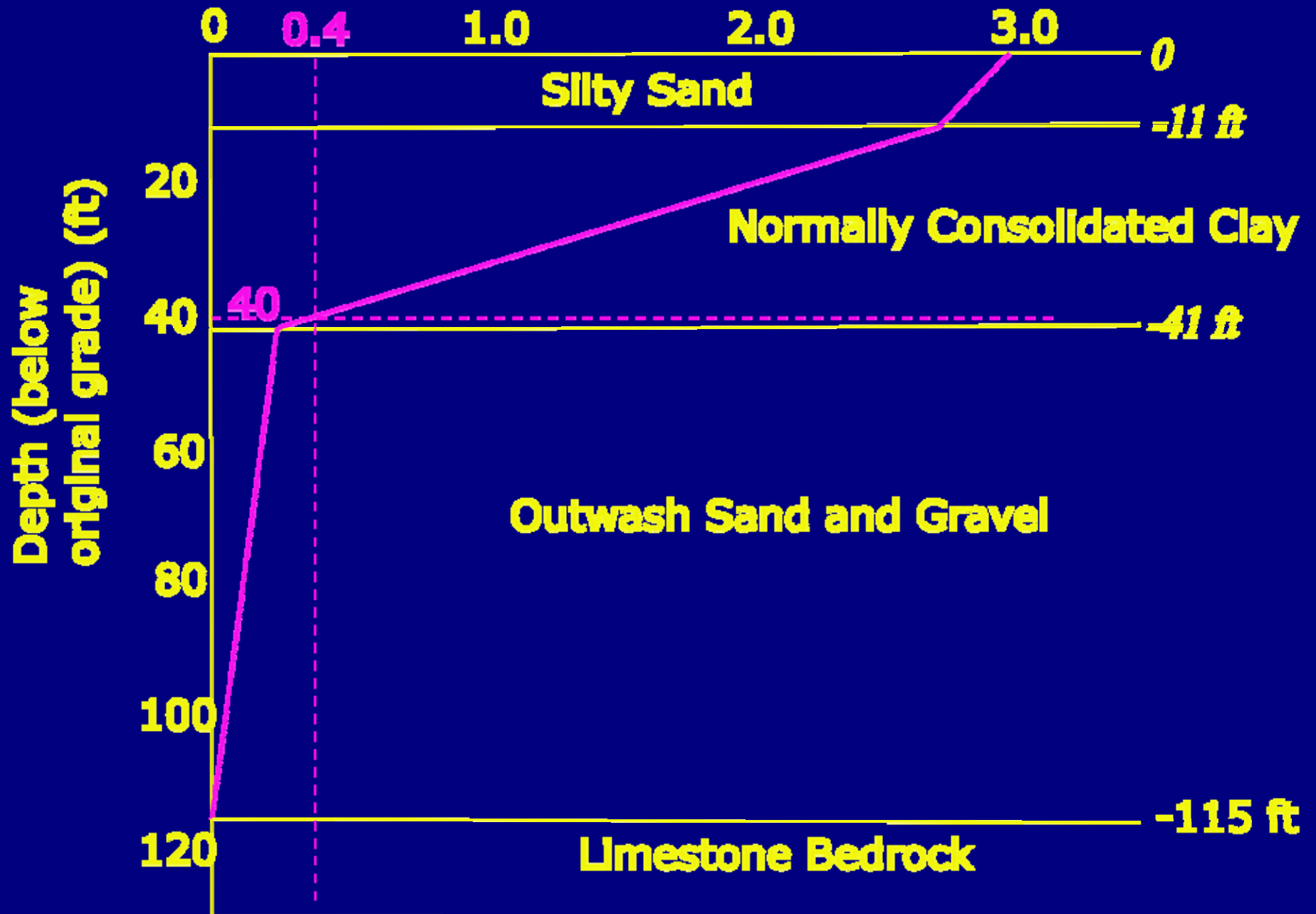
# Soll Profile



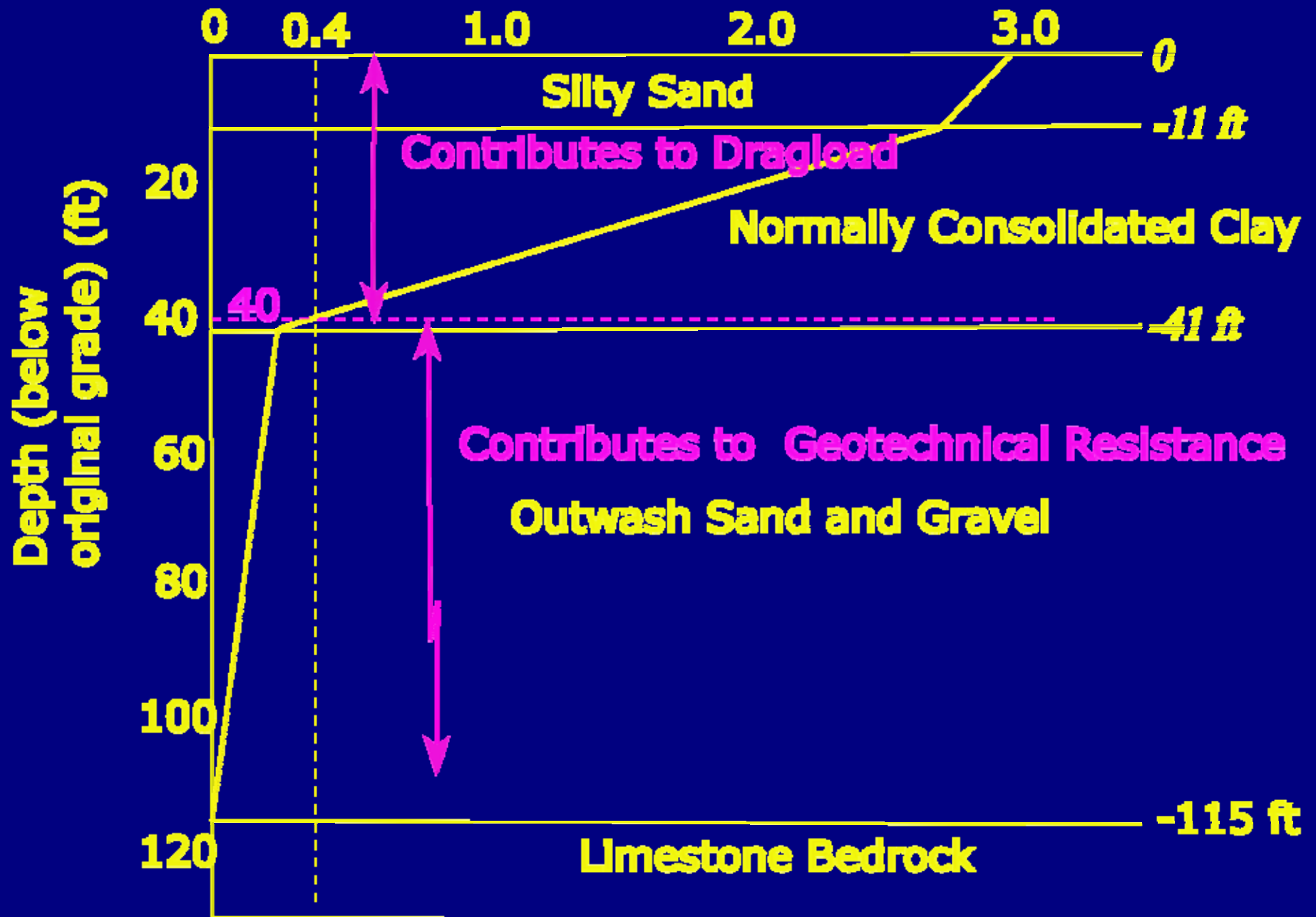
# Settlement (s)



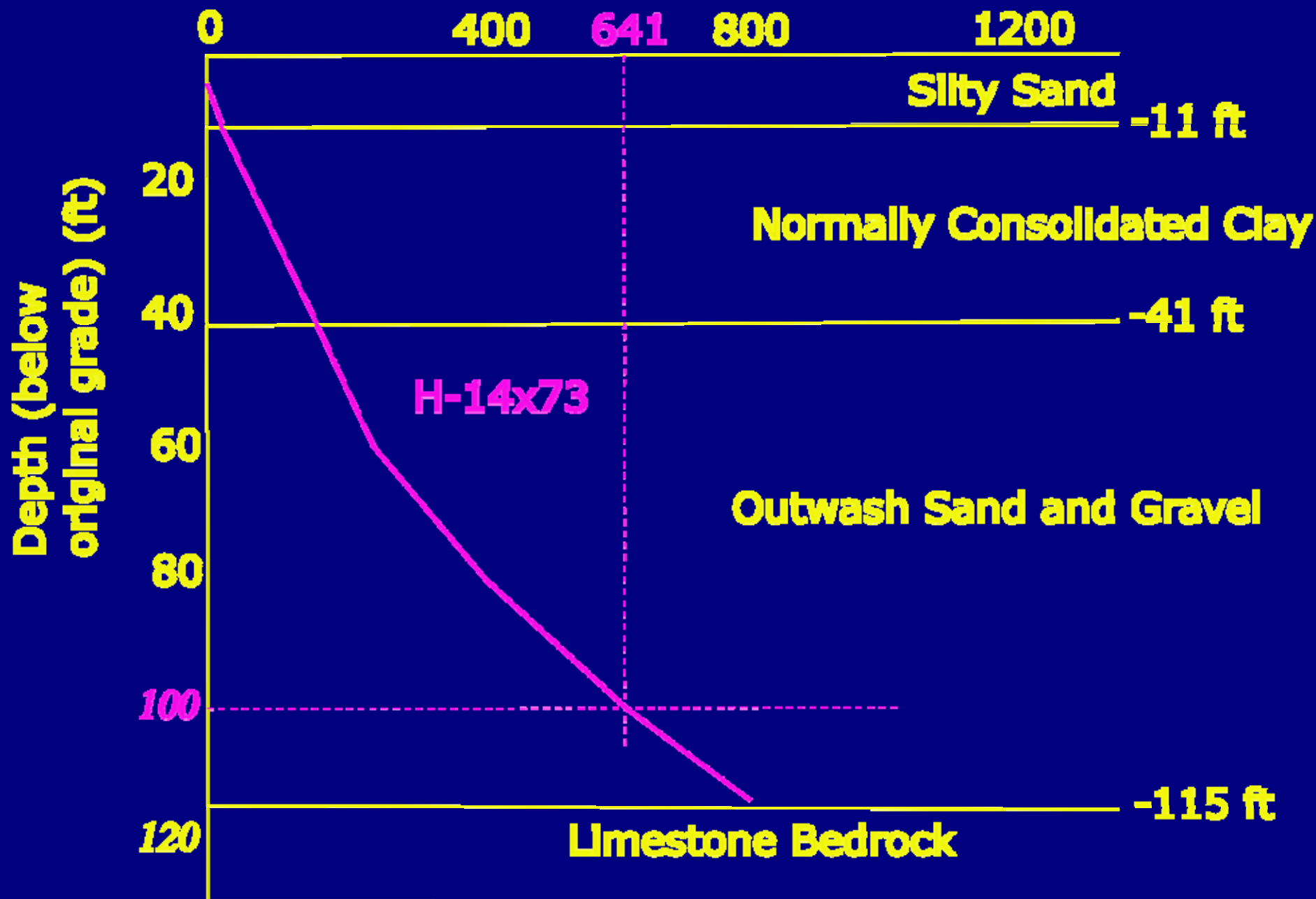
# Settlement Profile (Inches)



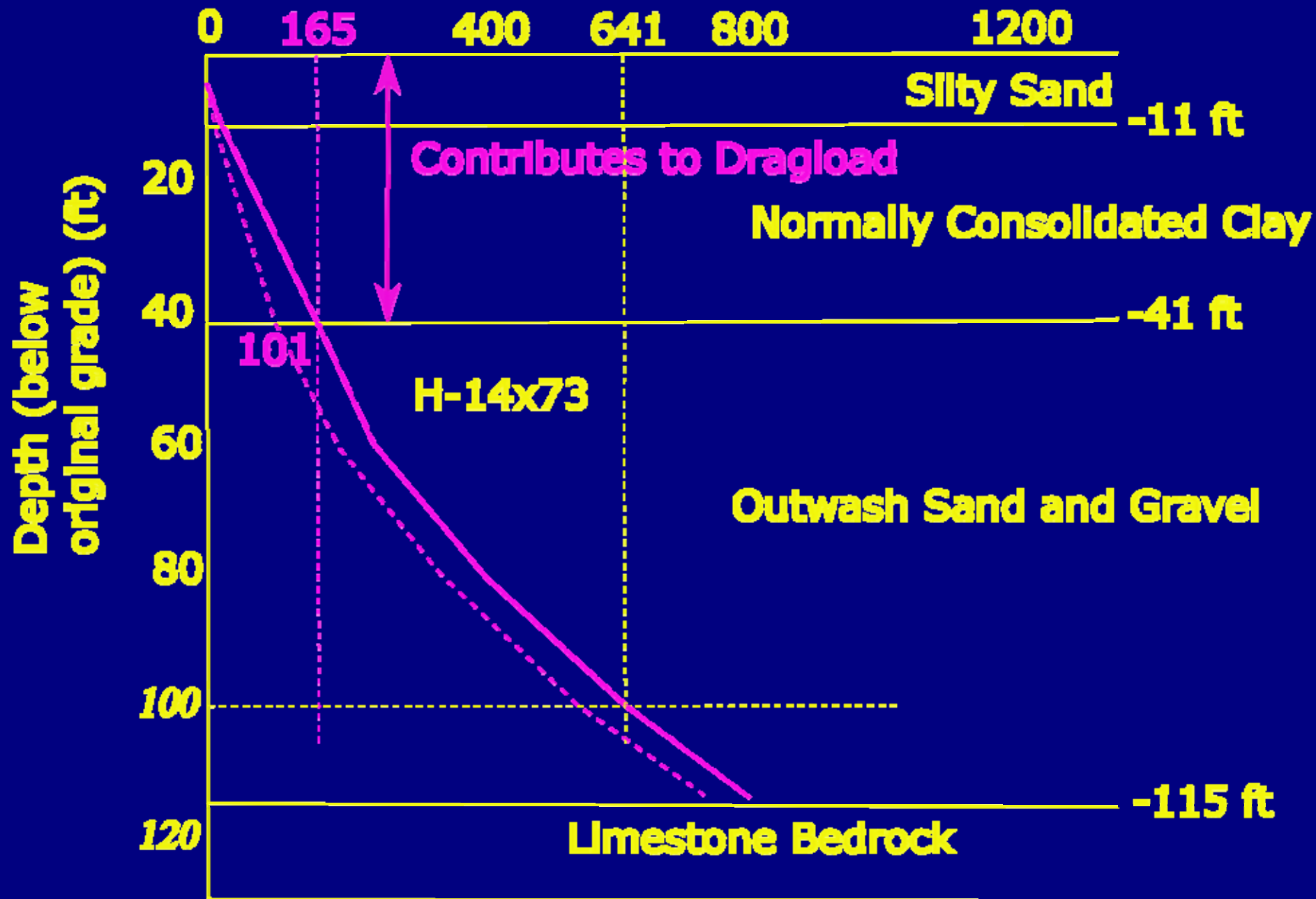
# Settlement Profile (Inches)



# Nominal Geotechnical Resistance (klps)



# Nominal Geotechnical Resistance (2) (kips)



Applying Resistance Factors (0.35 -0.45)  
the factored geotechnical resistance of our  
100 ft pile becomes 227 kips. (~20% reduction)

But what about downdrag?

The 101 kip downdrag load has also to be included in the load calculation for the pile

101 kips x load factor (1.4) = 141 kips  
Net 'working' load = 227 -141 kips

We now have a 100 foot pile with a  
working capacity of 86 kips

(and 200 feet away, the same pile – with no  
embankment surcharge - will be allowed  
to carry 280 kips)

Factored maximum resistance (no DD) = R

Factored 'productive' resistance (considering DD) = N

$$\text{DD efficiency} = \frac{N \times 100}{R} \%$$

<u>Pile Type</u>	<u>Load Transfer</u>	<u>Length (ft)</u>	<u>Efficiency</u>
H 12x53	friction	100	15%
H 14x73	friction	100	31%
H 14x89	friction	100	39%
H 12x53	end bearing at rock	115	40%
H 14x73	end bearing at rock	115	50%
H 14x89	end bearing at rock	115	59%
30" shaft	friction	110	54%
48" shaft	friction	110	45%
30" shaft	end bearing at rock	115	85%
48" shaft	end bearing at rock	115	88%

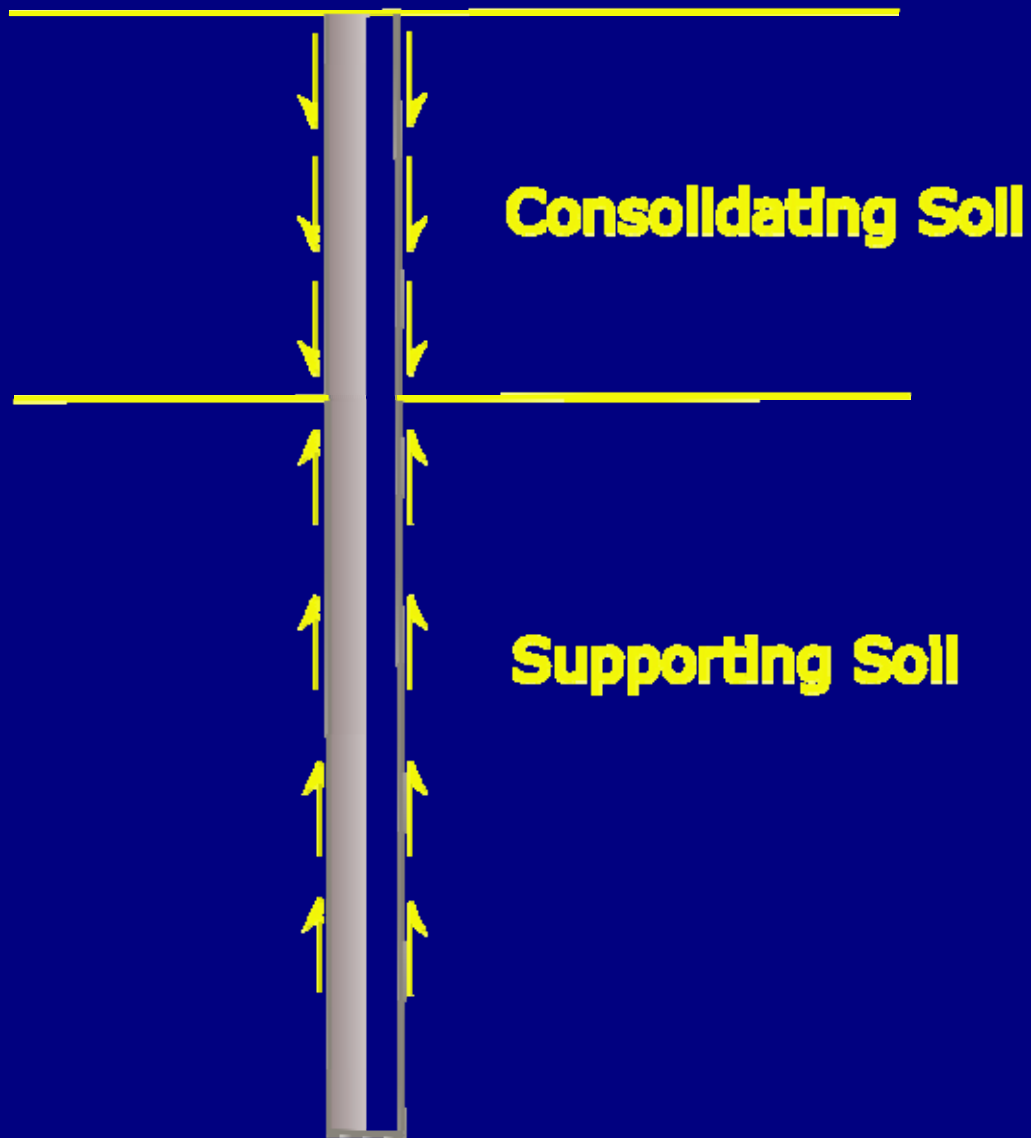
# Modes of Failure

Important distinction must be made between

Strength limit state – where things break, and

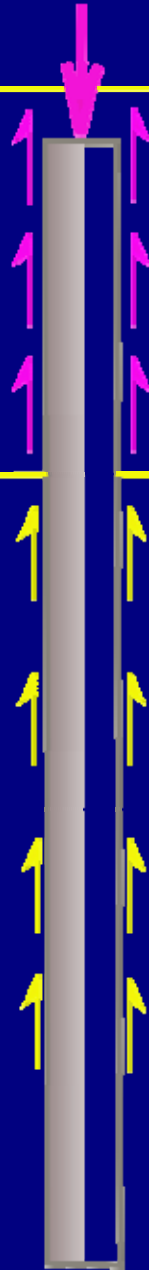
Service limit state – where things have moved enough  
to where they don't work very well  
any more

# Classical Downdrag (DD)



**DL + LL**

## **NeoDowndrag (DD)**



**Consolidating Soil**

**Contributes to Geotechnical Resistance**

**Consider the Strength Limit State - Failure caused by application of dead and live loads - the shear forces in the consolidating soil have been reversed**

**NO DRAG, NO LOAD - (just a failed pile!)**

**Supporting Soil**

**Contributes to Geotechnical Resistance**

# NeoDowndrag – what is it?

Numerically, NeoDowndrag is identical to Classical Downdrag.

The difference lies simply in a reappraisal of the stress conditions in the soil at the strength limit state, so changing when and how dragload is applied.

References: Fellenius B.H. 1984, 1998, 2004

(The logic seems irrefutable - and is not rebutted in the literature.)

## NeoDowndrag – the beginning

“In opposition to what the author has recommended in the past, the dragload must not be included in the consideration of geotechnical capacity”

Fellenius B.H. 1984,

# NeoDowndrag – key elements (1)

“Shaft shear – negative skin friction or shaft resistance – develops for very small movement, often no larger than the compression of the pile caused by the design load .....with time, all piles will develop negative skin friction and drag loads”

Fellenius B.H. 1998

(this means 1-2 mm, not 10 mm [0.4 inches] specified in current design manuals)

## NeoDowndrag – key elements (2)

“The dragload will not have any influence on the pile bearing capacity and the dragload must not be subtracted from the pile capacity when determining the allowable load. Neither must the dragload be added to the design loads when checking that the loads from the structure do not exceed the allowable load”

Fellenius B.H. 1998

(current design specifications mandate the contrary)

## NeoDowndrag – key elements (3)

“From a geotechnical view, the dragload is a beneficial force prestressing the pile and reducing the deformation that occurs from live loads. As long as the pile structural strength is not exceeded, the larger the dragload, the stiffer and better the pile foundation. Beyond the name, there is nothing negative about negative skin friction”

Fellenius B.H. 1998

## NeoDowndrag – key elements (4)

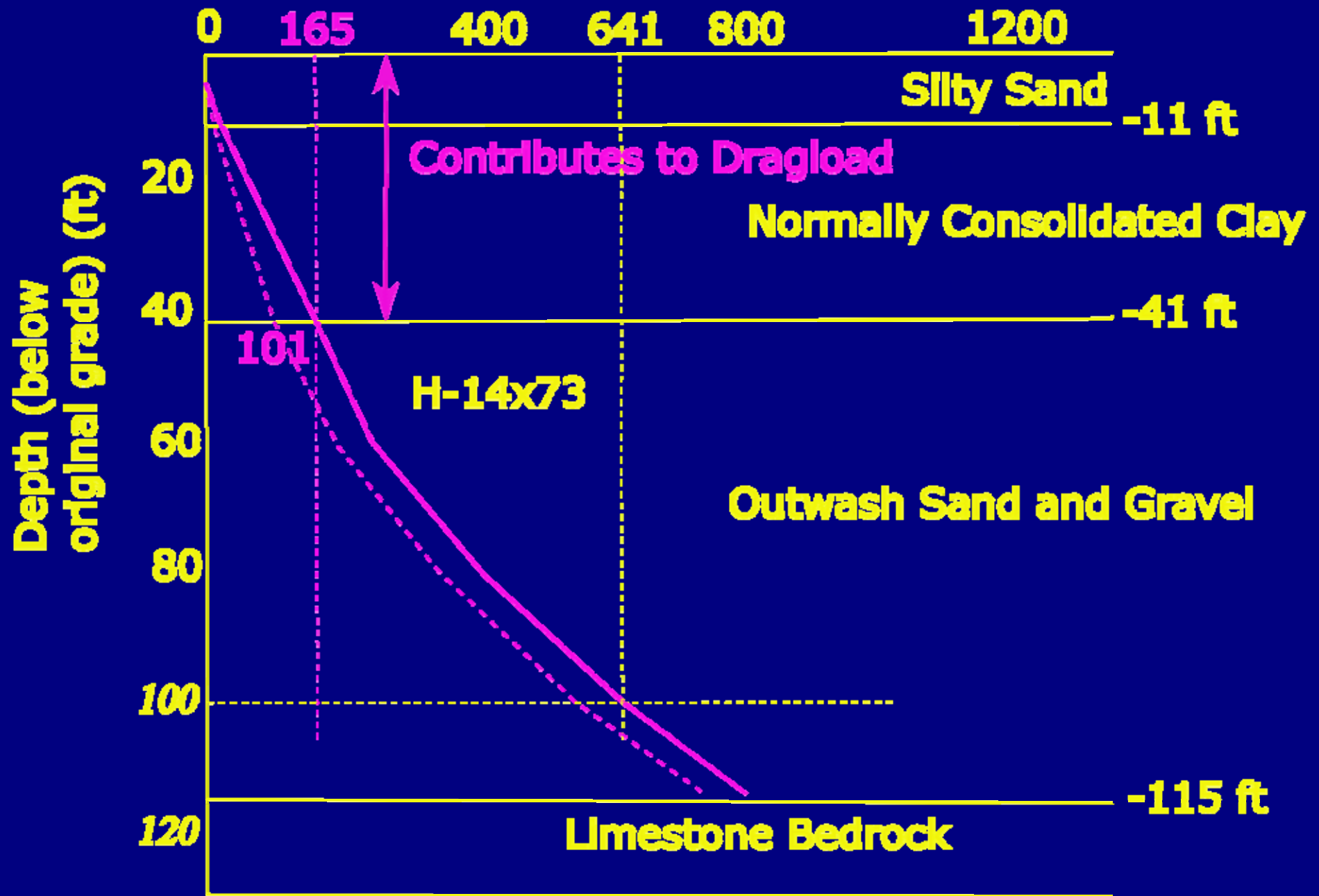
“Historically, negative skin friction is associated with large settlement. However the problem is not that of dragload, but of downdrag. Downdrag occurs where the pile settles with the soil and is associated with a small dragload. The neutral plane is where the pile and the soil settle equally. Therefore, the problem of downdrag has to be addressed in an analysis that determines the location of the neutral plane and the soil movement at the neutral plane”

Fellenius B.H. 1998

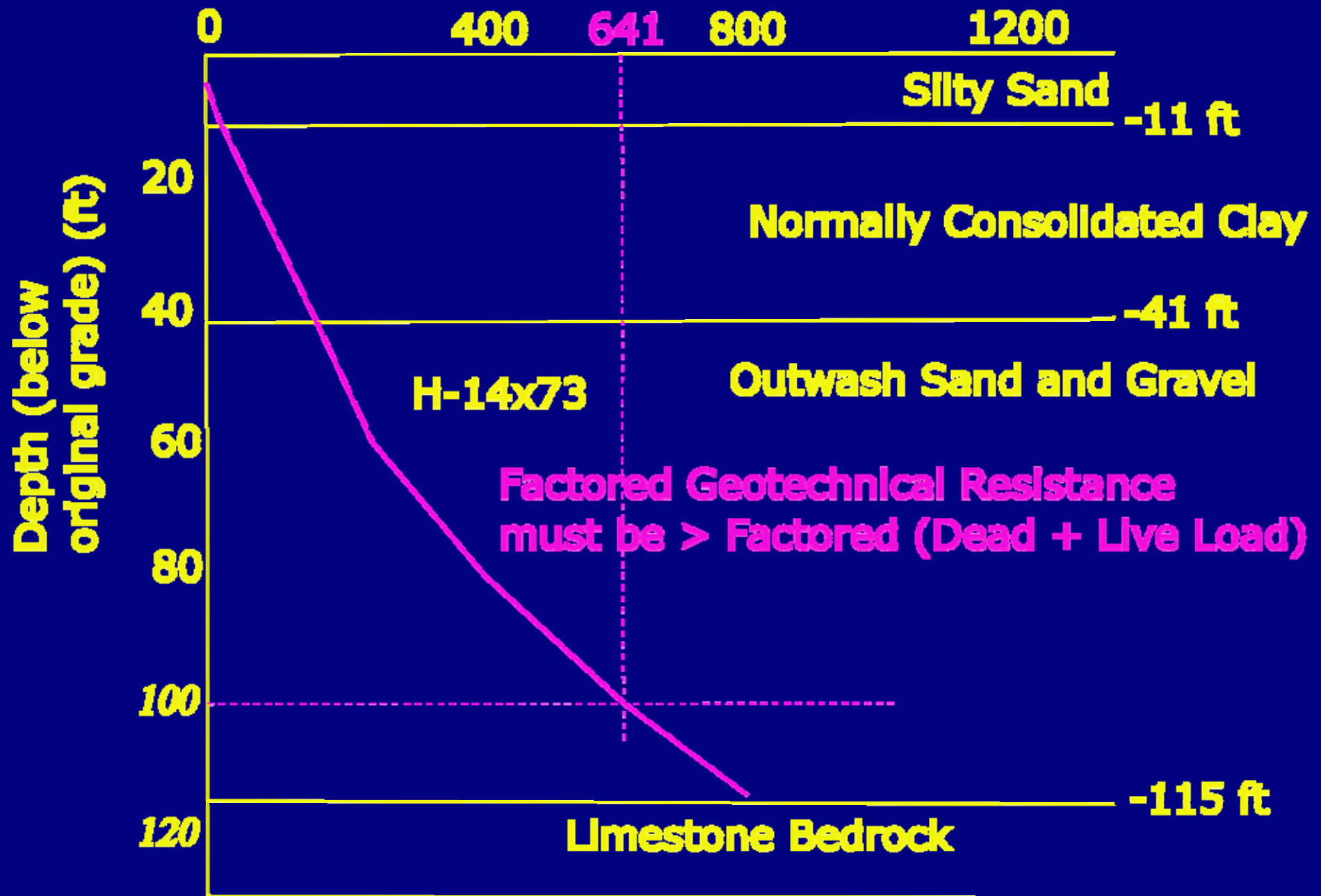
(current design specifications do acknowledge the value of such an analysis and in some jurisdictions it is required)

## Case History (2)

# Nominal Geotechnical Resistance (2) (kips)



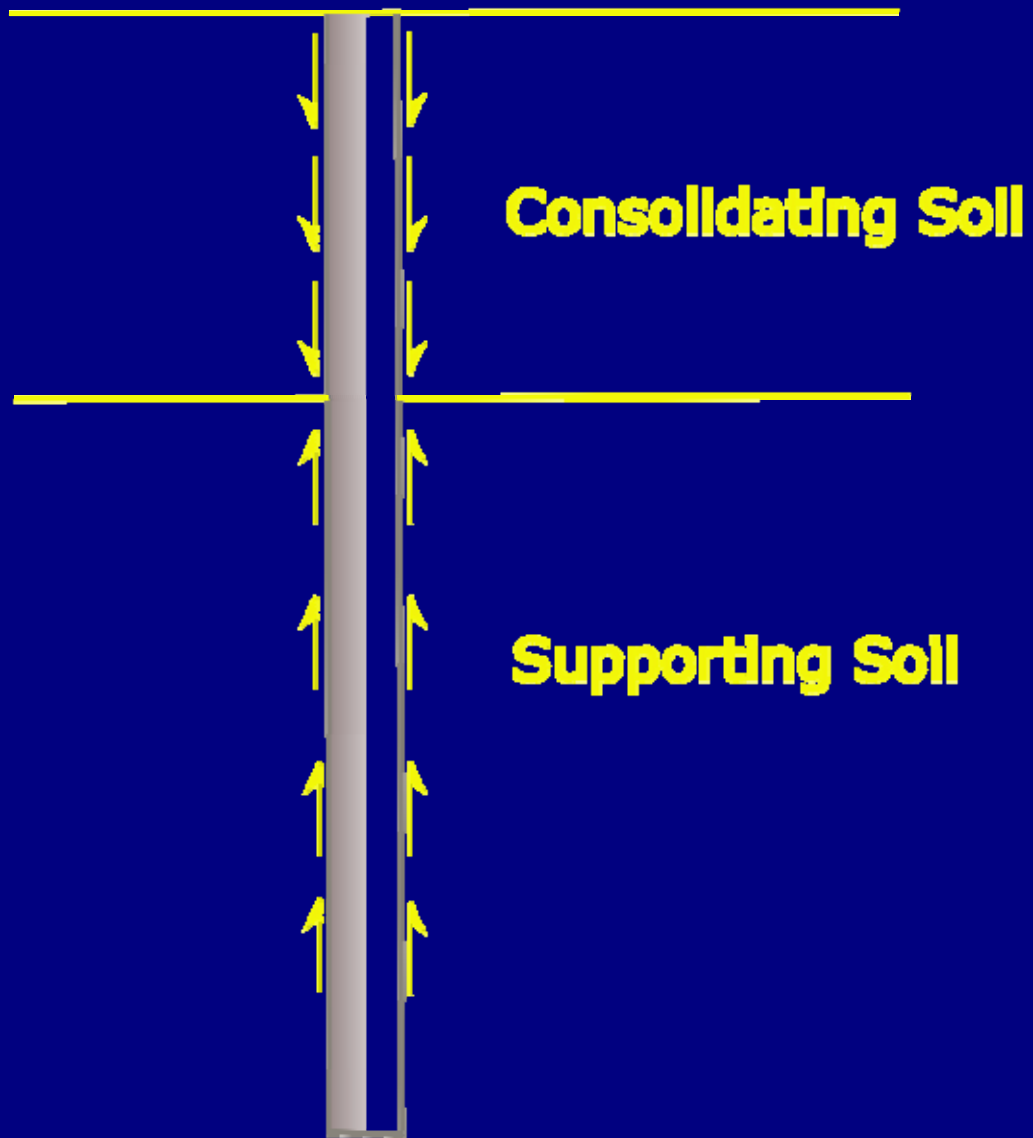
# Nominal Geotechnical Resistance (kips)



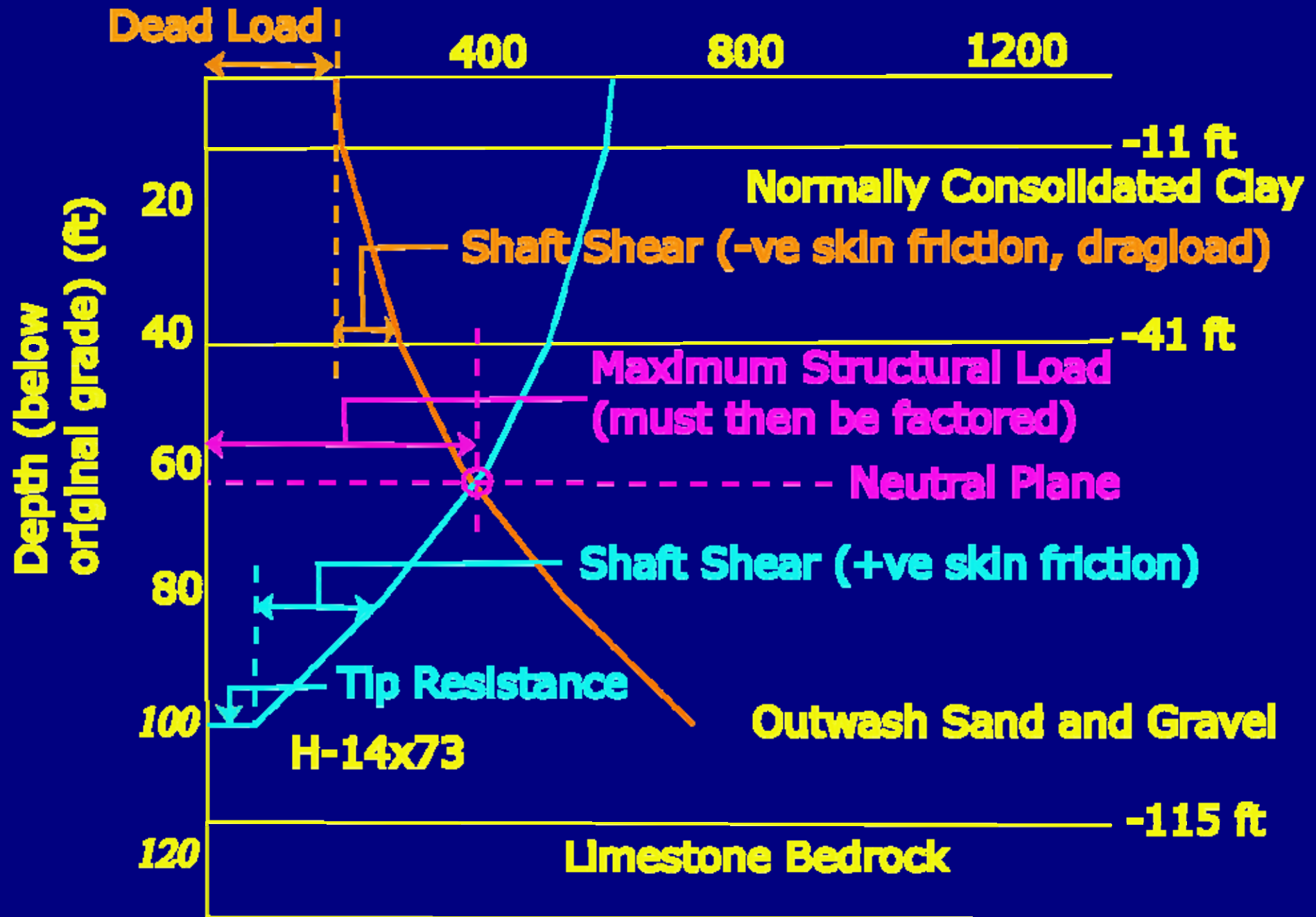
## Unified Design of Piled Foundations

- Capacity Analysis  
(geotechnical strength limit state)
- Structural Analysis  
(structural strength limit state)
- Settlement Analysis  
(geotechnical service limit state)

# Classical Downdrag (DD)



# Neutral Plane Determination



# Cost Implications of Classical Downdrag

For the case history:

Downdrag efficiency (classical) 31%

Classical downdrag design 3 x 100 H-14x73  
Cost at \$46 / foot \$13,800

Downdrag efficiency (neo) 100%

Neodowndrag design 1 x 100 H-14x73  
Cost at \$46 / foot \$4,600

What are others doing about this?

Caltrans and PennDot have developed some language in their design specifications to soften the impact of classical downdrag.

Government of Hong Kong Geotechnical Manual (2006) embraces neodowndrag 100%

Eurocode 7 (1997) – Geotechnical Design – Includes downdrag as a load at ultimate (strength) limit state, but emphasises soil/structure interaction

## Suggestions -

for the Geotechs: 1) Write report recommendations based on design specification methods, but include discussion of neowndrag and the cost implications. 2) Perform a settlement analysis to satisfy service limit state – for the pile group, if multiple piles are to be used – not just one pile.

for the Structuralists: Insist on a neutral plane analysis before finalizing the structural design of piles.

for agencies charged with writing and implementing design specifications: This is worth taking another look at.

.... and finally, always remember that

“Engineering is the art of modelling materials we do not wholly understand, into shapes we cannot precisely analyse, so as to withstand forces we cannot properly assess, in such a way that the public has no reason to suspect the extent of our ignorance.”

Dr. A.R. Dykes Institution of Structural Engineers,  
1976