Brief Historical Overview of Yield Strength Determination in ACI 318

Hot Topic Session: High-Strength Reinforcing Bars – Balancing Design Requirements with Achievable Material Properties
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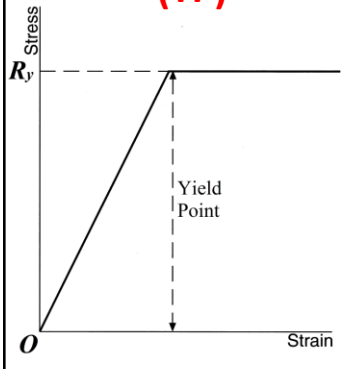
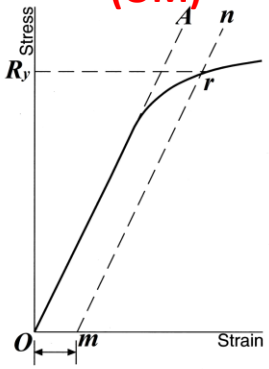
Methods for Measuring Yield Stress

Observed Yield Point (YP)

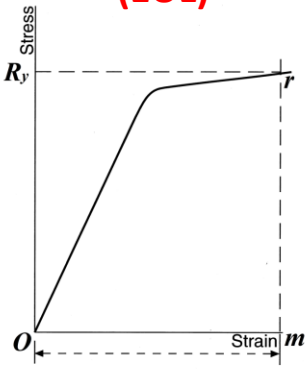


Offset Method (OM)



Om=Specified Offset

Extension Under Load (EUL)



Om=Specified Extension Under Load

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When did ACI 318 first specify a method?

- ACI 318-63: "When reinforcement is used that has a yield strength, f_y, in excess of 60,000 psi,at a proof stress equal to the specified yield strength, f_y, the strain does not exceed 0.003."
  - The "exception" can be associated with the progression to USD (ultimate strength design) because, in ACI 318-63, the "exception" applied only to members designed using the USD method.
- ACI 318-71: "For reinforcing bars with a specified yield strength, f_y, exceeding 60,000 psi, f_y shall be the stress corresponding to a strain of 0.35 percent."
  - This is based on the recommendations of a 1968 "Ad Hoc Group on Reinforcement."
- ACI 318-14: Currently anticipated to be essentially the same.
  - However, a code change submittal currently under ballot proposes to change to the 0.2% offset method

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Arguably, Code Provision is Obsolete

This provision first appeared about 50 years ago, and is based on actual stress-strain behavior of bars as manufactured in the 1960s.

Much has changed since then: manufacturing processes are different, and numerous other reinforcement products now included; these other products have differing stress-strain behaviors.

Time has come to change the yield method provisions within ACI 318.

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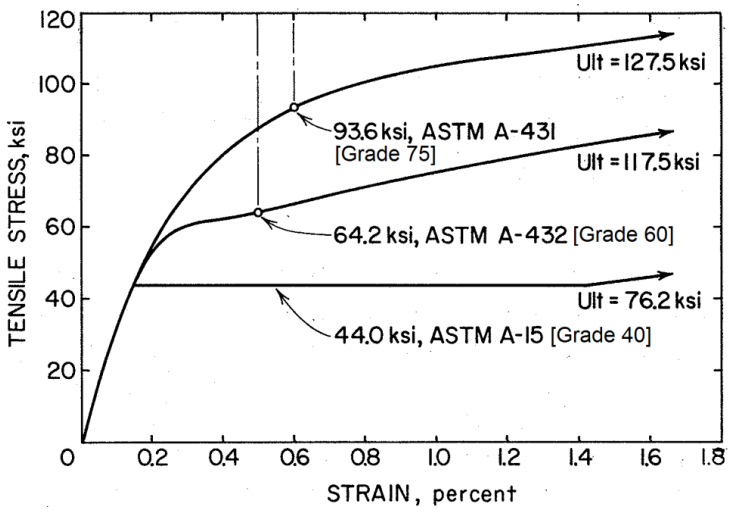
Circa 1963 Actual Stress Strain Curves



- Grade 75 ASTM A431 bars ***never exhibited*** a distinct yield point
- Grade 60 ASTM A432 bars exhibited in-between stress-strain behavior
- Grade 40 ASTM A15 bars were ***always*** sharply-yielding materials

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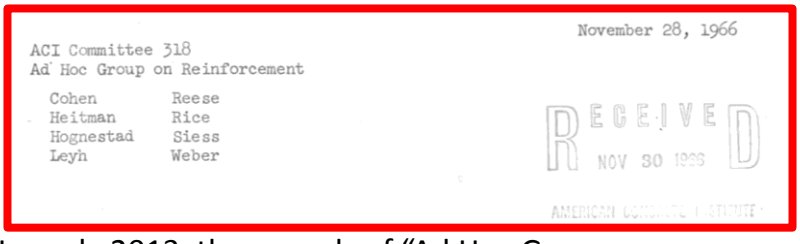
ACI 318 Ad Hoc Group on Reinforcement



November 28, 1966

ACI Committee 318
Ad Hoc Group on Reinforcement

Cohen	Reese
Heitman	Rice
Hognestad	Siess
Leyh	Weber

RECEIVED
NOV 30 1966
AMERICAN CONCRETE INSTITUTE

- In early 2013, the records of "Ad Hoc Group on Reinforcement" were found in the committee correspondence archives at ACI headquarters
- The ad hoc group appears to have operated during 1966, 1967, 1968
- "DRAFT of a Report" issued March 8, 1967
- "Report" issued April 10, 1967
- 1967 and 1968: Interaction with ASTM committees and follow-up laboratory testing; ad hoc group expanded in size at that time to include steel producers and others

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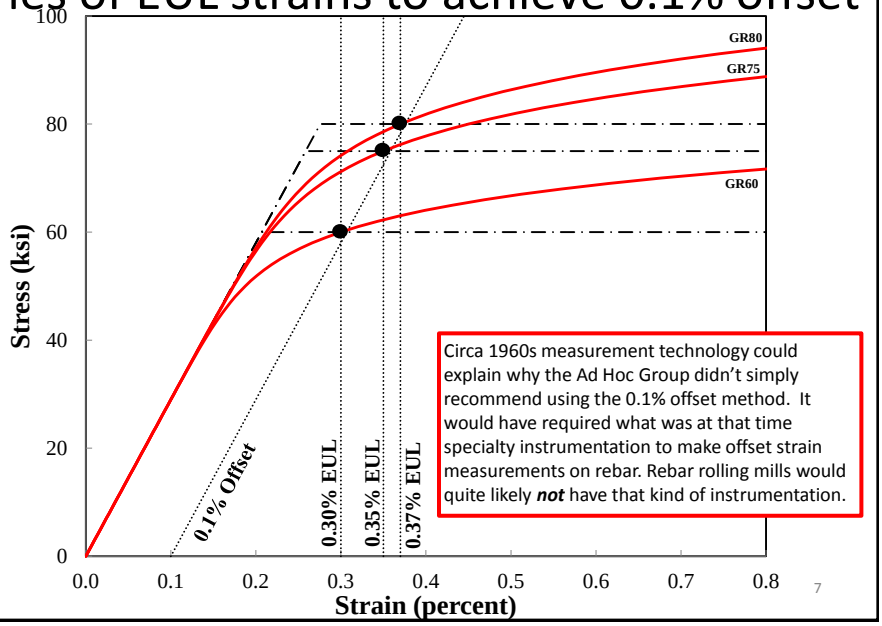
1967 Ad-Hoc Group recommendation: Series of EUL strains to achieve 0.1% offset



Circa 1960s measurement technology could explain why the Ad Hoc Group didn't simply recommend using the 0.1% offset method. It would have required what was at that time specialty instrumentation to make offset strain measurements on rebar. Rebar rolling mills would quite likely ***not*** have that kind of instrumentation.

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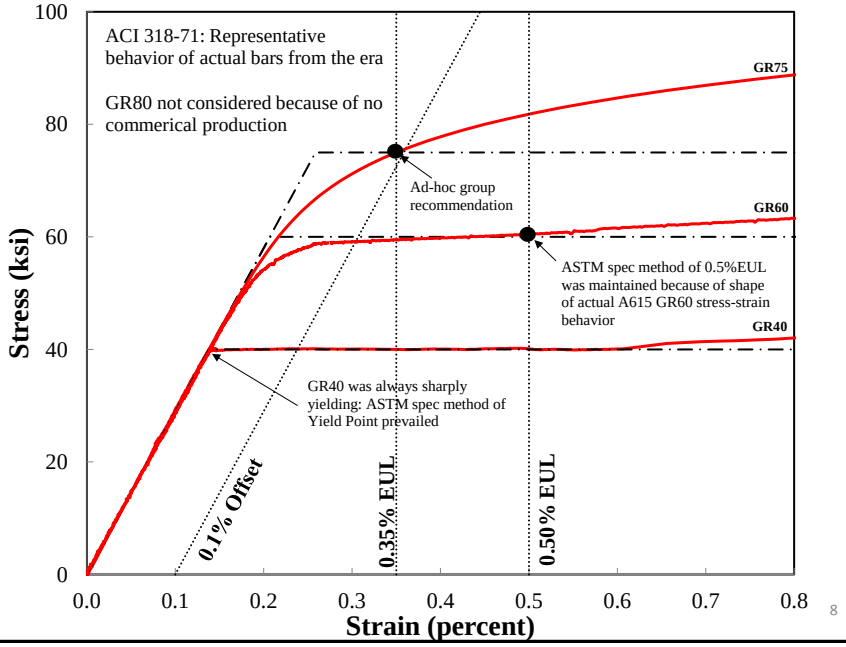
ACI 318-71



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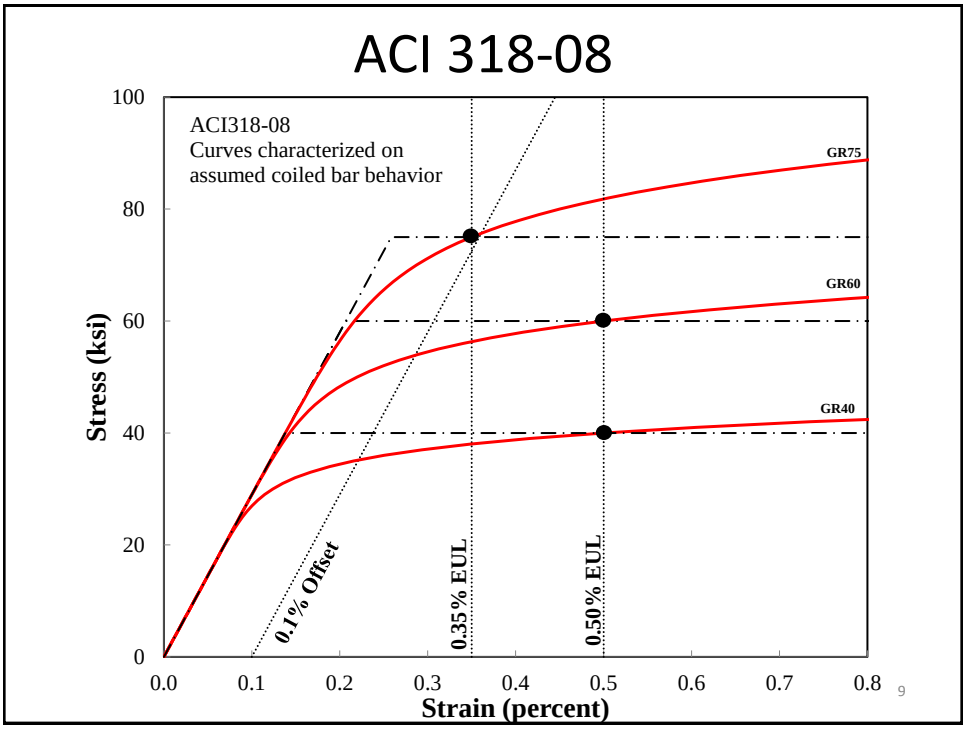
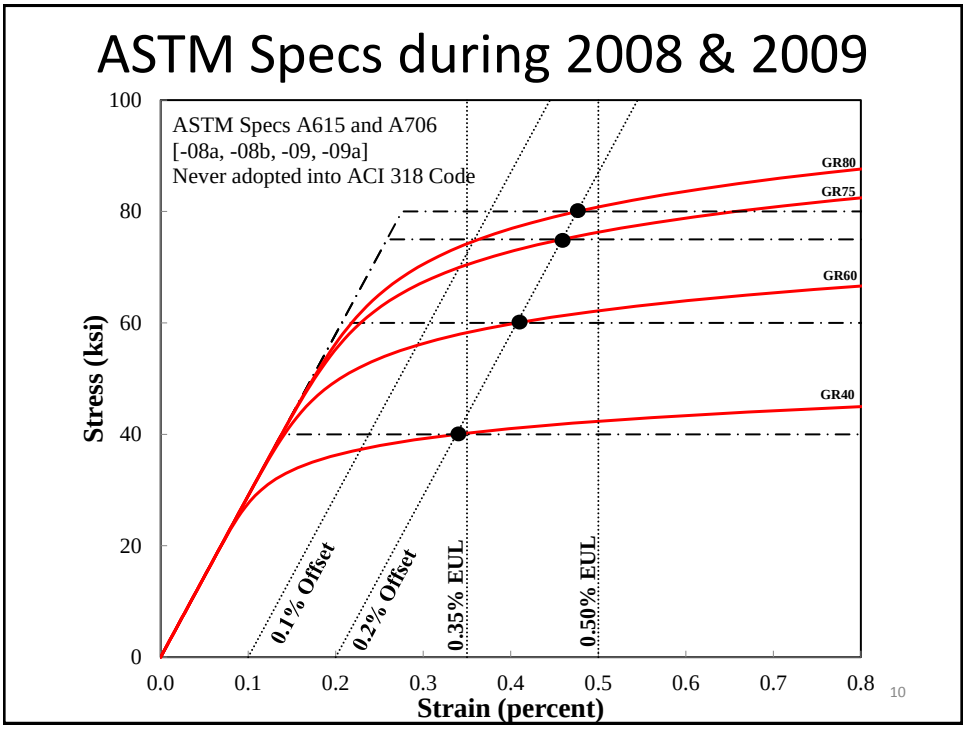
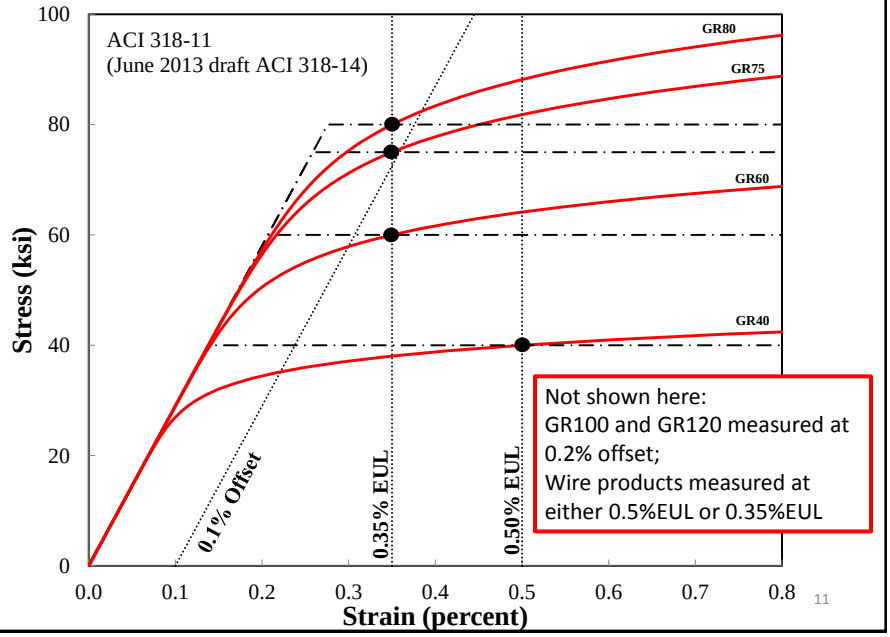

ACI 318-08
ACI318-08
Curves characterized on
assumed coiled bar behavior
GR75
GR60
GR40
0.1% Offset
0.35% EUL
0.50% EUL
Stress (ksi)
Strain (percent)
100
80
60
40
20
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
9


ASTM Specs during 2008 & 2009
ASTM Specs A615 and A706
[-08a, -08b, -09, -09a]
Never adopted into ACI 318 Code
GR80
GR75
GR60
GR40
0.1% Offset
0.2% Offset
0.35% EUL
0.50% EUL
Stress (ksi)
Strain (percent)
100
80
60
40
20
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
10

ACI 318-11 (anticipated 318-14)



Not shown here:
GR100 and GR120 measured at 0.2% offset;
Wire products measured at either 0.5%EUL or 0.35%EUL

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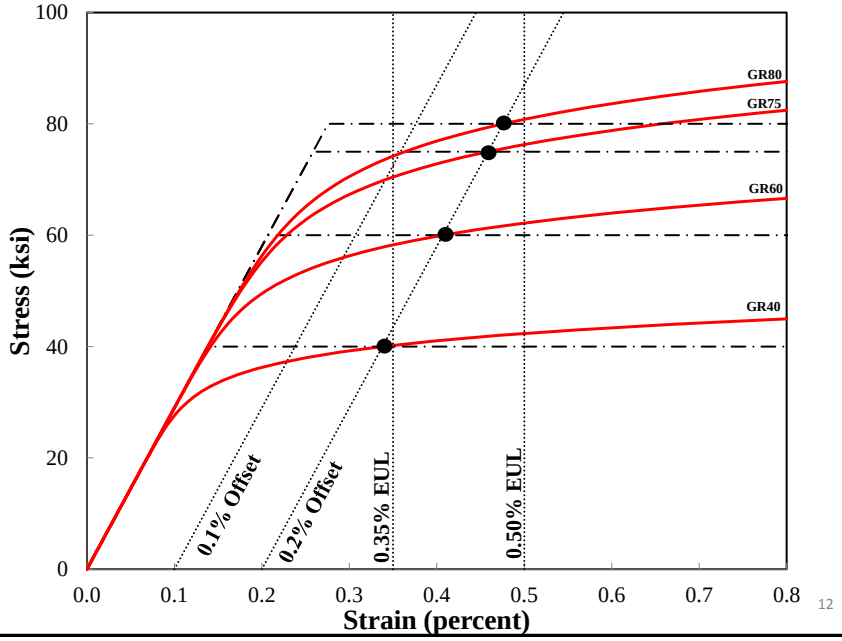
ACI 318-14 Proposed Code Change CB006



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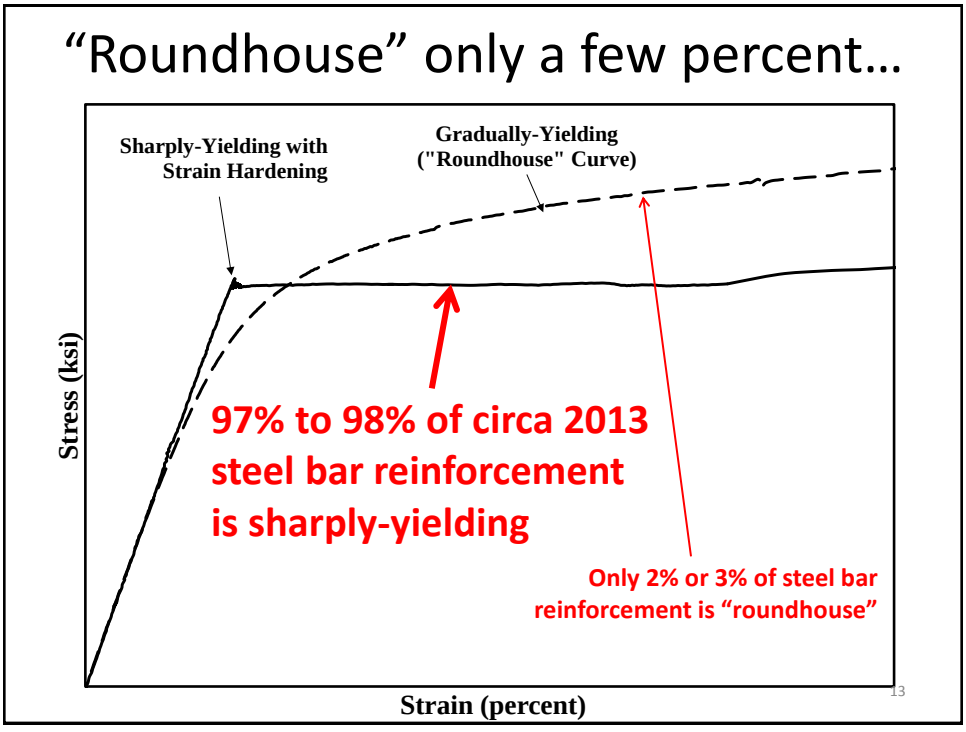
"Roundhouse" only a few percent…
Sharply-Yielding with Strain Hardening
Gradually-Yielding ("Roundhouse" Curve)
Stress (ksi)
97% to 98% of circa 2013 steel bar reinforcement is sharply-yielding
Only 2% or 3% of steel bar reinforcement is "roundhouse"
Strain (percent)
13