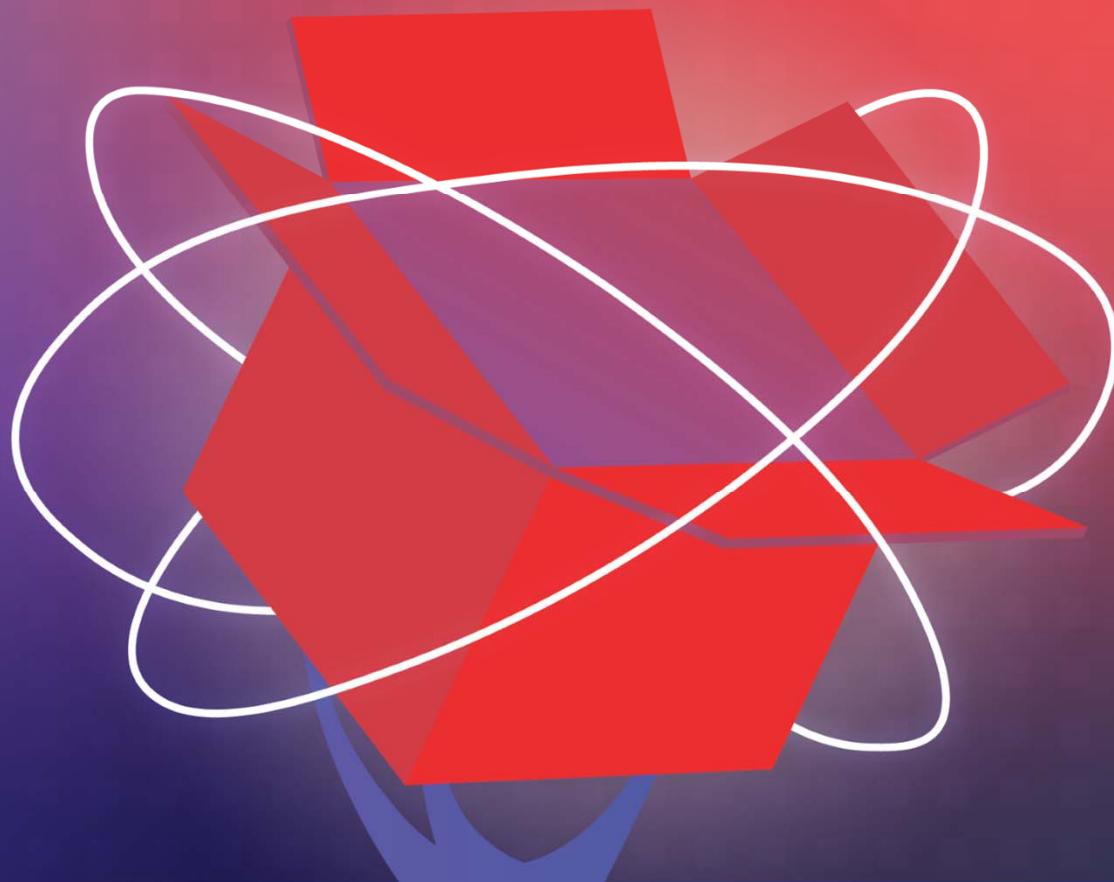


Compressive Strength Measurements for Containers and Components: A Review

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The Many Roles of a Box

- To identify the contents and market the products [printing]
- To contain contents, moving multiple items with single actions [handling]
- To protect contents from the rigors and hazards in the distribution environment
 - Singularly [small parcel shipment]
 - In units, in transit, storage and under load [compression]
 - Over time [lifetime and creep]
- If package fails in any of these, the product may not get sold

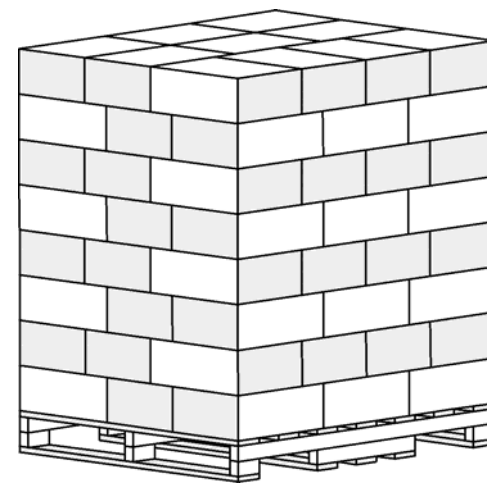
Physical
measurement

Lots of Ways to Evaluate Compression Strength

- We shall see
 - Different length scales interact
 - Key metric will depend on the perspective of interest
- Industry continues to explore and refine understanding
 - Citations throughout this presentation
 - 1960's-2020's

Box Compression Strength

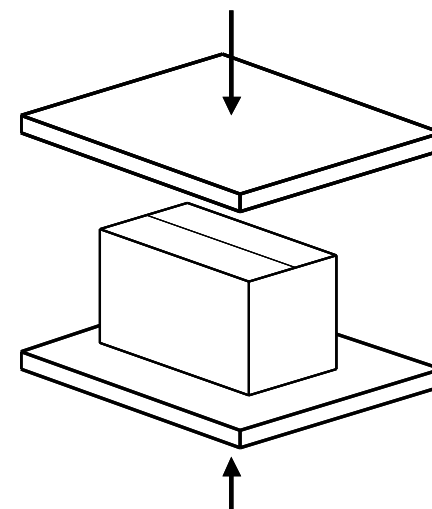
- How much strength does a box need?
 - Boxes support strength in their corners
 - Impacted by environment
 - Will depend on how it is used



Resources: Fibre Box Handbook

Box Compression Strength

- How much strength does a box need?
- How much strength does a box have?
 - Measured in a short time test
 - Fixed or Floating Platen
 - Fixed is referee (and used for all modeling)
 - Related to actual use, but different

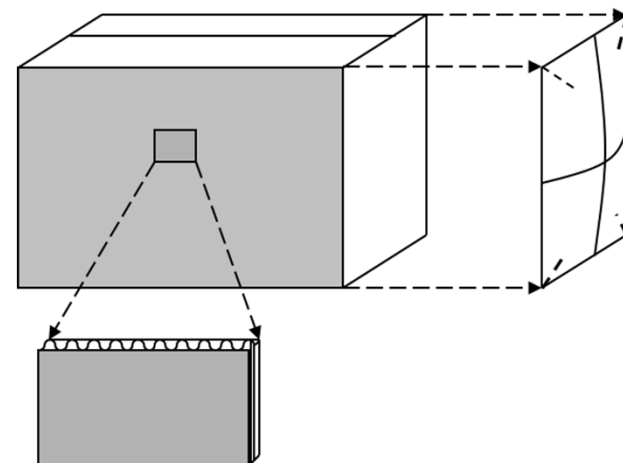


Resources: TAPPI T 804

Frank, *Packaging Technology and Science* 27(2): 105(2014)

Box Compression Strength

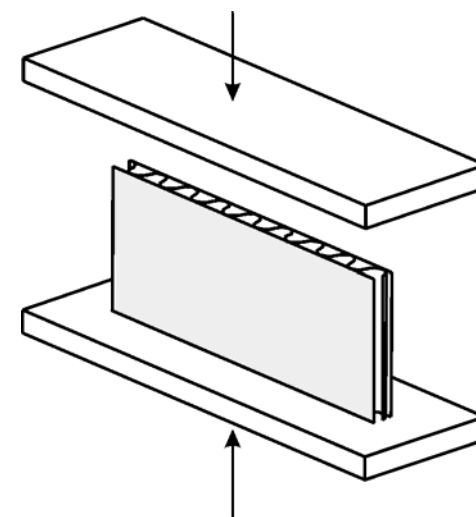
- How much strength does a box need?
- How much strength does a box have?
- Where does box strength come from?
 - Size
 - Stiffness
 - Material strength (ECT)



Resources: McKee, et.al., *Paperboard Packaging* 48(8): 149(1963)
Urbanik, et.al., *Wood and Fiber Science* 38(3): 399(2006)
Coffin, *TAPPI Journal* 14(8): 537(2015)

Material Strength Measured By The Edge Crush Test (ECT)

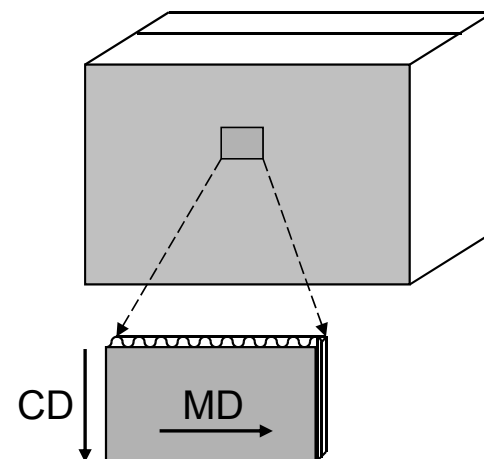
- Compressive strength of the combined board
 - Bulk material property of the structure
 - Thinner board types, more flutes, more structure



Resources: Koning, *Tappi* 43(3): 134(1964)
Eriksson, *Boxboard Containers* March 1979

Material Strength Measured By The Edge Crush Test (ECT)

- Compressive strength of the combined board
- Depend on paper strength
 - CD Strength for the typical box
 - $ECT = A + B \cdot \text{liner str.} + C \cdot \text{medium str.}$
 - Stronger papers, well combined
→ Higher ECT

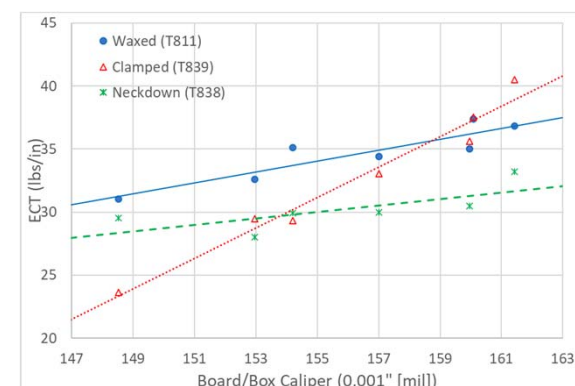
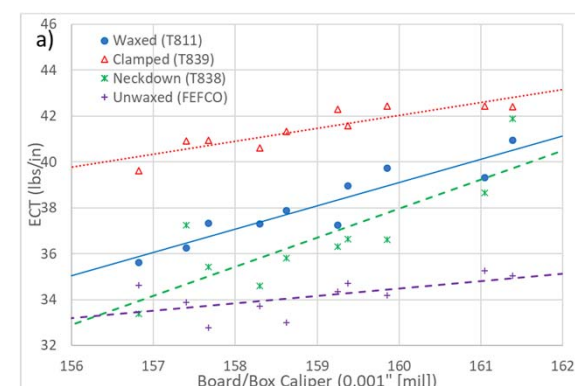


Resources: Seth, *TAPPI Journal* 68(3): 98(1985)
 Jakubiszyn, et.al., *Przegląd Papierniczy* 58(5), 287(2002)
 Schaepe, et.al., *Corrugating International* Sept 2006

Material Strength Measured By The Edge Crush Test (ECT)

- Compressive strength of the combined board
- Depend on paper strength
- Many different methods
 - Give different results, don't scale
 - Clamp (T839) most common
 - Waxed (T811) is referee
 - Required to validate a BMC on a box
 - Attempt to mimic failure mode of material in a container

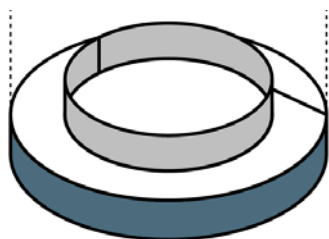
Resources: TAPPI T811, T838, T839, FEFCO 8, NMFTA Rule 41
Popil, *BioResources* 7(2): 2553(2012)
Frank, et.al., *TAPPI Journal* 21(8): 418(2022)



Paper Strength Measurement- Linerboard

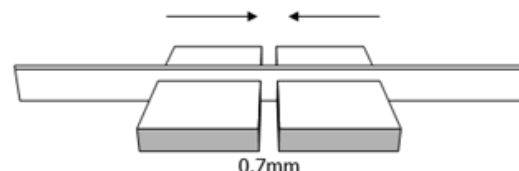
Ring Crush

- Compressing a 6" long strip on a $\frac{1}{4}$ " span, shaped to reduce impact of buckling
- Failure a mix of compressive strength and buckling/bending resistance
- Combining network and fiber strengths



Short Span Compression (SCT/STFI)

- Compressing a 15mm high strip on a 0.7mm span
- Failure avoids buckling, measures "pure" compression
- Fiber length scale, fiber strength test



Resources: TAPPI T822, T826

Batelka, J.J., *Corrugating International* 2(4): 163(2000)

Fellers, et.al., Chapter 9 in Handbook of physical testing of paper, ISBN 0824704983

Paper Strength Measurement- Linerboard

- But how do boxes fail?
- Russell Allan:
“If I am interested in monitoring paper machine performance... I use SCT as my compression test. If I am interested in how my product will perform out in the market place... I choose Ring Crush.”
- ECT correlates better with liner RC

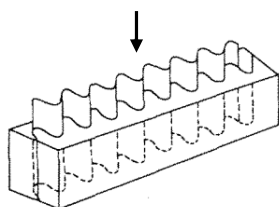


Resources: Allan, R., *Appita Journal* 56(2): 88(2003)
Frank, B., *TAPPI Journal* 6(9): 10(2007)

Paper Strength Measurement- Medium

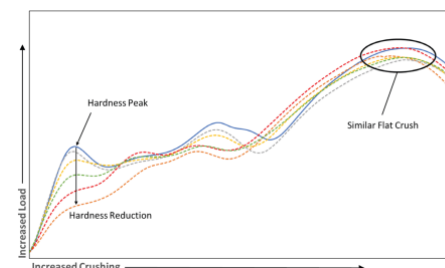
Cross Direction

- Ring Crush
- SCT/STFI
- CFC (corrugated fluted crush)
 - Flute a sample, measure the strength edge-on



Machine Direction

- CMT
 - Flute a sample, measure the strength of the structure
- Hardness
 - First peak in load curve
- S-Test

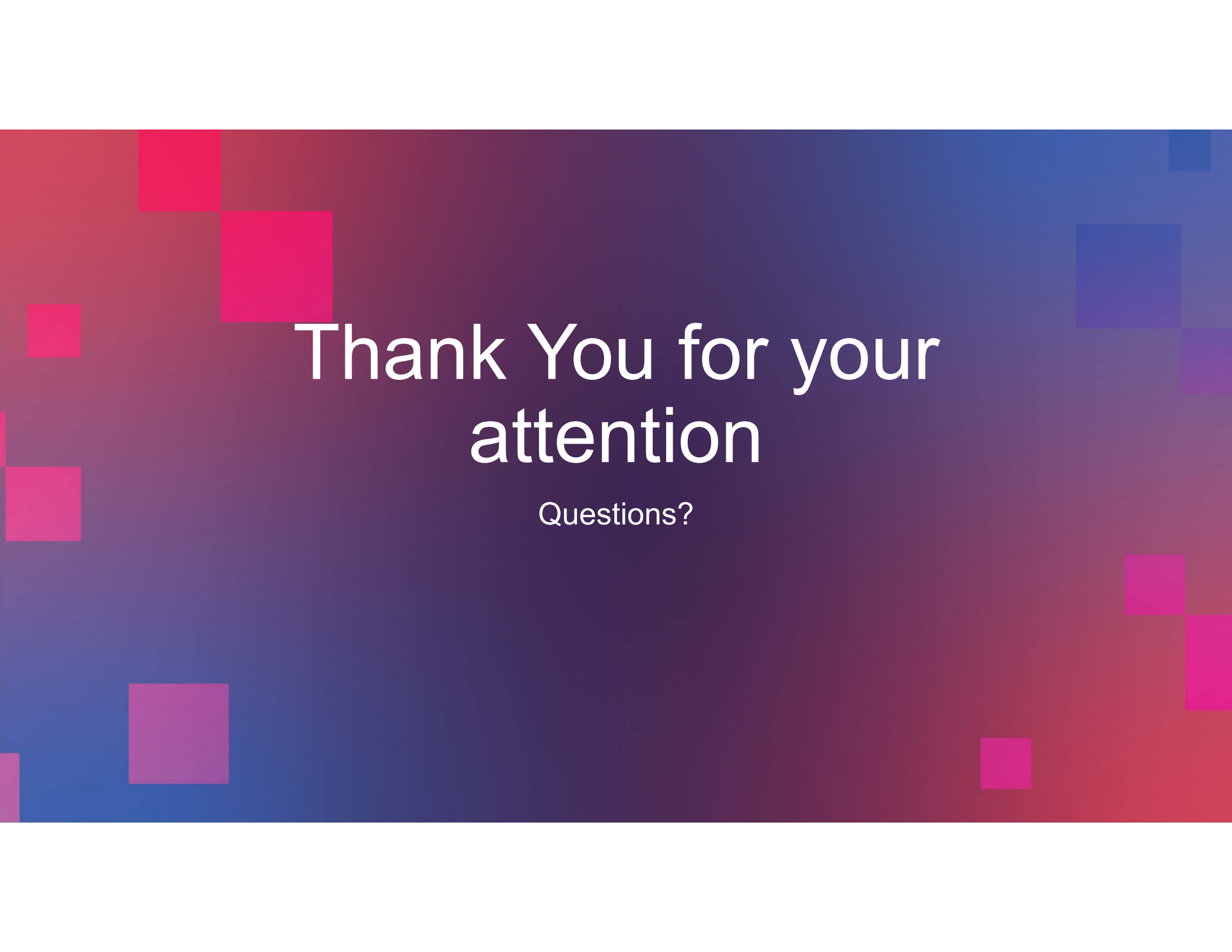


Resources: TAPPI T822, T826, T843, T809, ISO 7763
Crisp, C.J., et.al., *TAPPI*, 51(5): 80A(1968)

Furst, T., et.al. , *ATIP* 70(2): 15(2016)
Cash, D., et.al., *TAPPI Journal* 18(3), 161(2019)

Lots of Ways to Evaluate Compression Strength

- Different length scales interact
- Key metric will depend on the perspective of interest
 - Different players in the industry pursue different tests
- Industry continues to explore and refine understanding
 - 1960's-2020's
- All these tests
 - Help verify the box can do its job
 - MUST make sure you are using the right one for your task
 - Strive to help us meet our customers' needs



Thank You for your attention

Questions?