



September 8-12, 2024
Orange County Convention Center, Orlando, FL

Time Tested. **Future Forward.**

**Our Time is Now.
Be Ready for Tomorrow.**

www.supercorrexpo.org

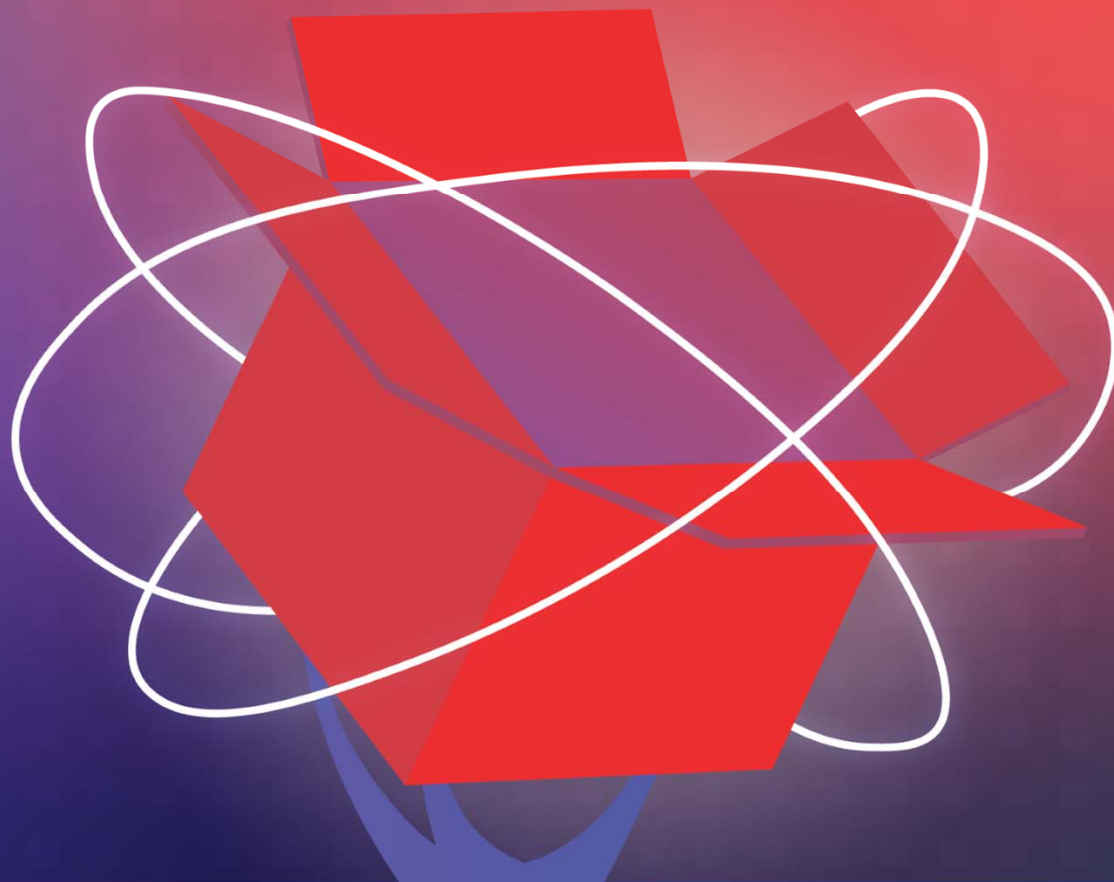


Creep Lifetime Performance of Containers

Douglas W Coffin

Department of Chemical, Paper, and
Biomedical Engineering

Miami University



Compressive Strength vs Performance

- We specify compressive strength
 - Container: BCT
 - Combined Board: ECT
 - Components: SCT, RC, CFC
- We tend to find higher strength correlates to better performance
- But rarely is a container loaded to complete compressive failure
 - Failures occur from impact, shock, environmental changes, sustained loads over time,
 - These are not the same as compressive strength failure



Time Tested. Future Forward.

Corrugated Paperboard is the Choice Material for Containers

- Except some of the attributes that make paper a great choice also leads to other performance problems
- Cellulosic-based paper
 - Semi-ductile material that can absorb energy
 - Can not sustain load over time (stress–relaxation, creep)

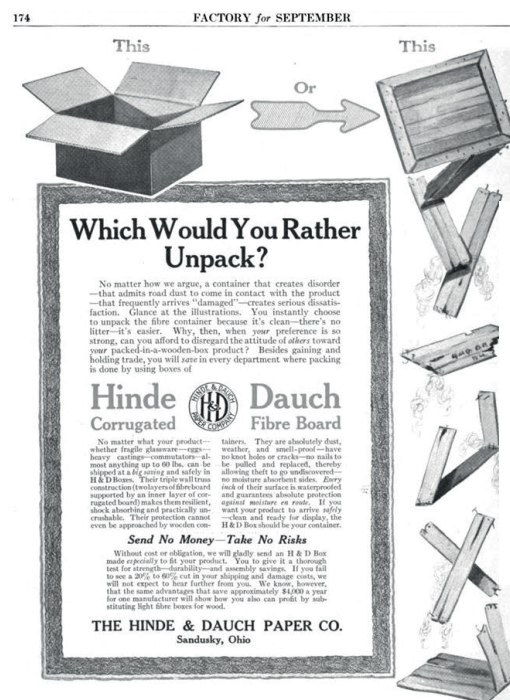


Figure 1.4. An Advertisement from 1914 capturing the essence of the war between wood and corrugated containers²⁰

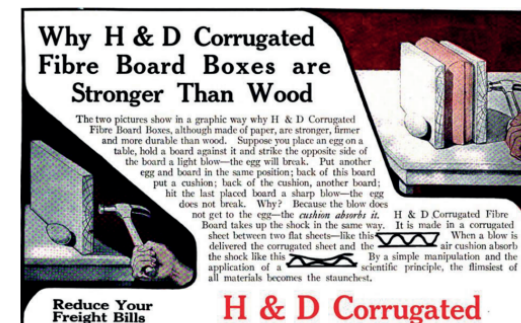
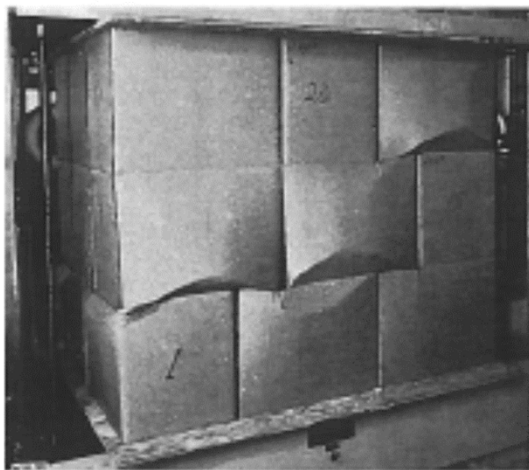


Figure 1.8. Hinde & Dauch advertisement from 1911 showing the how through-the-thickness compliance allows for absorption of energy from shock²⁰

Example: Stacking boxes

- Boxes loaded in compression will deform (creep) over time.



**How long can they stand
1 day, 1 month, 1 year?
(This is lifetime)**

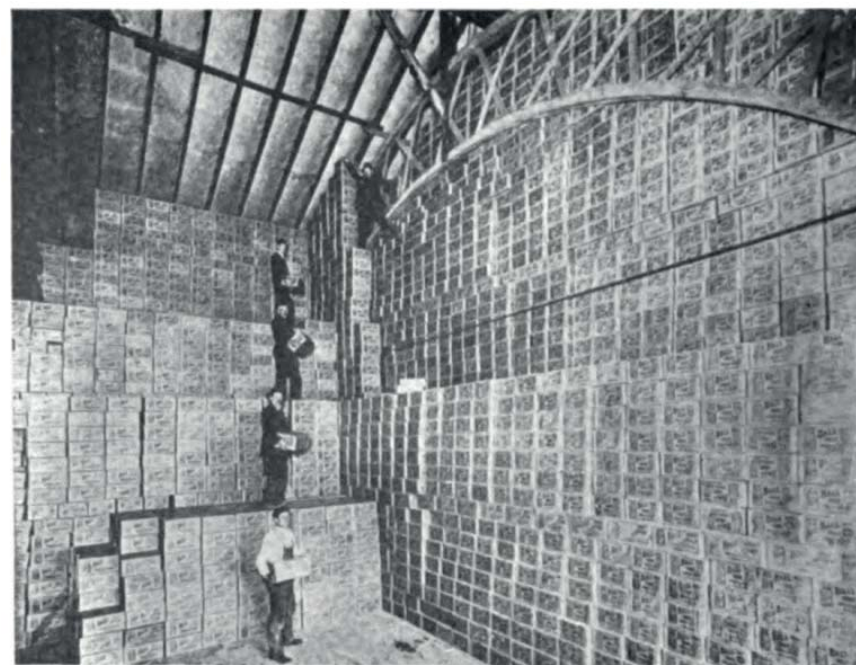
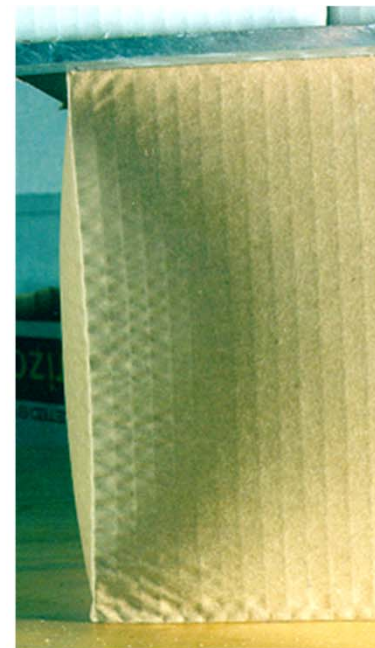
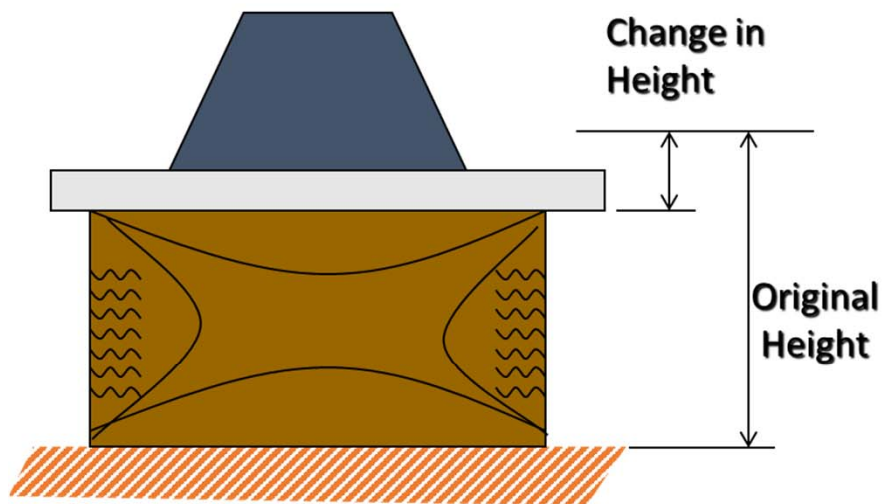


Figure 1.9. Photo from 1911 showing corrugated boxes packed with mason jars stacked up to 30 feet tall³²

How a Box Deforms

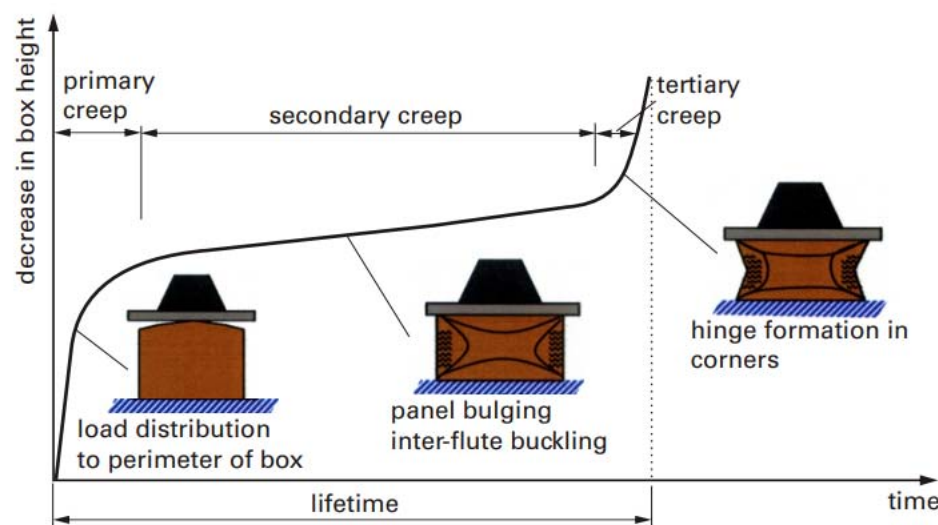
**A Box is
inherently an
unstable
structure in
compression**



**Box deforms in easiest manner
at center of panels = bulging
at vertical edges = inter-flute buckling**

Typical Response of Box under compression

- Failure occurs when the structure deforms to the point where it is unstable and can not sustain the load.
- The “tube” shape of a box is inherently unstable and imperfection sensitive

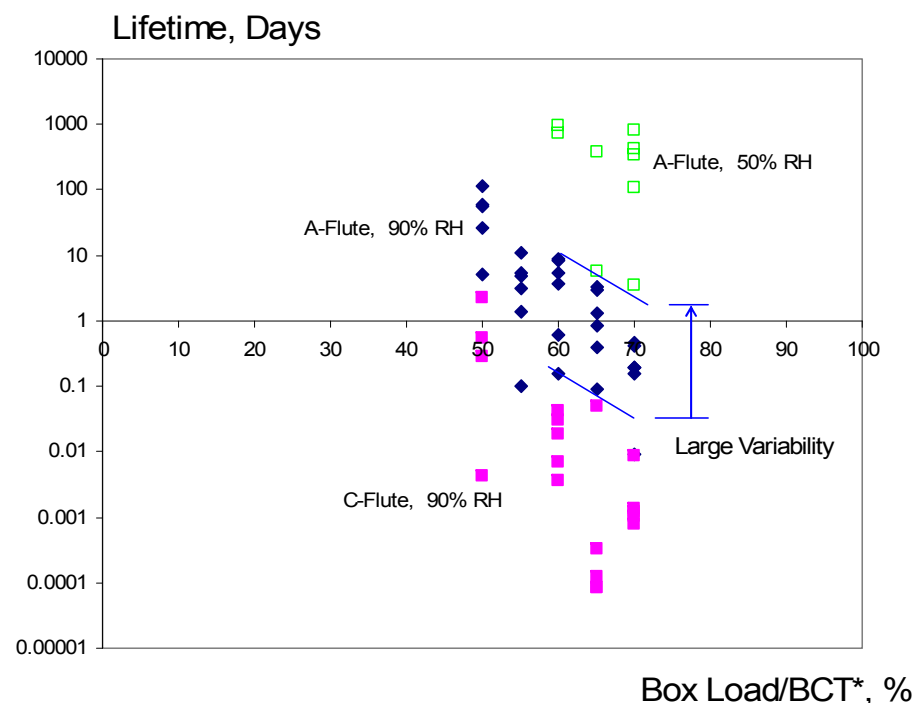


Lifetime is a function of
load level
defects, imperfections
environment

Time Tested. Future Forward.

The difficulty with Lifetime Prediction is Large Variability

- In general
 - Lifetime is longer the lower the load
 - The variability in lifetime is large
- Prediction is not easy
 - Same box type same load can produce lifetimes from less than one day to about 1 month.
- Distinguishing what makes a box have a long lifetime is not easy

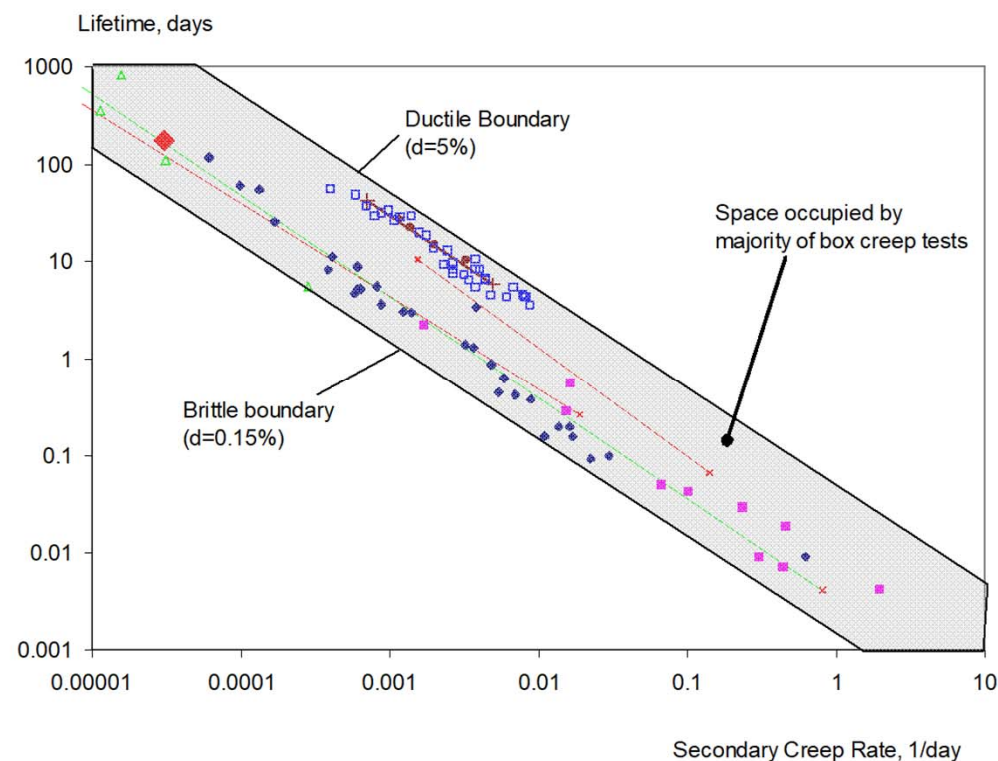


Data from Koning and Stern, *Tappi J* **60**(12)128-131 1977

Time Tested. Future Forward.

We have Observed a Correlation Many Times

- Secondary-creep rate correlates to lifetime
- This implies that boxes fail when the deformation reaches a critical level
 - When corners lose stability?
- Questions are
 - How do we make a box that creeps less for a given load?
 - How do we make a box that can sustain larger deformation?
 - How do we reduce variability?

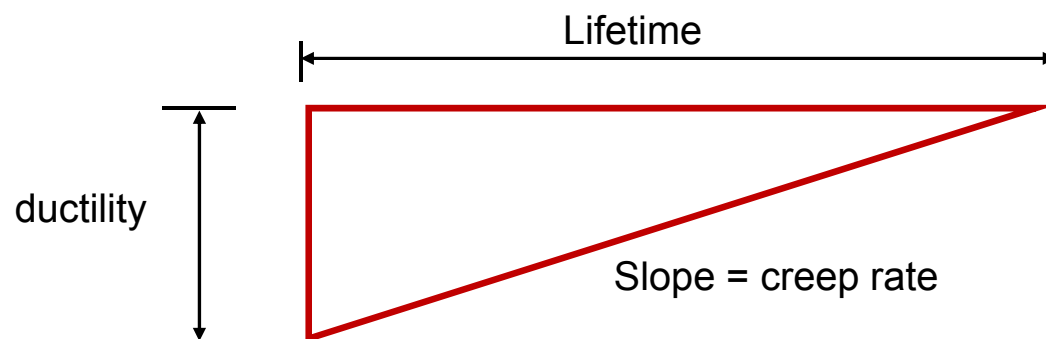
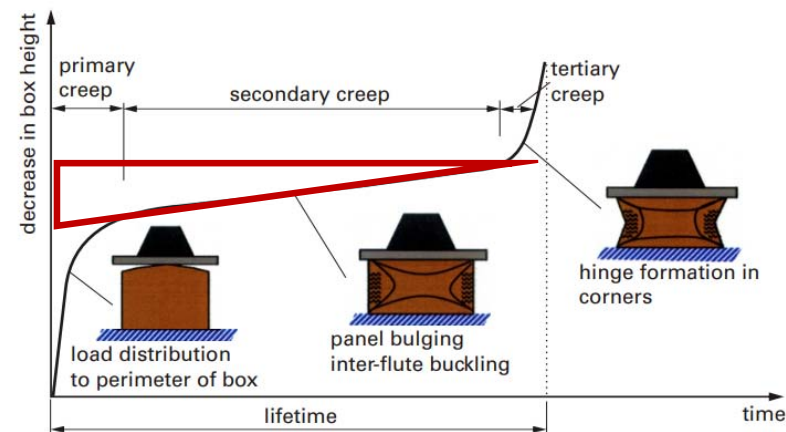


Lifetime Prediction

- $lifetime = \frac{ductility}{|creep\ rate|}$

Ductility is related to the top-to-bottom deformation that the box (side panels) can withstand before failure

Creep rate is related to how fast the box reaches this deformation at which the box fails.

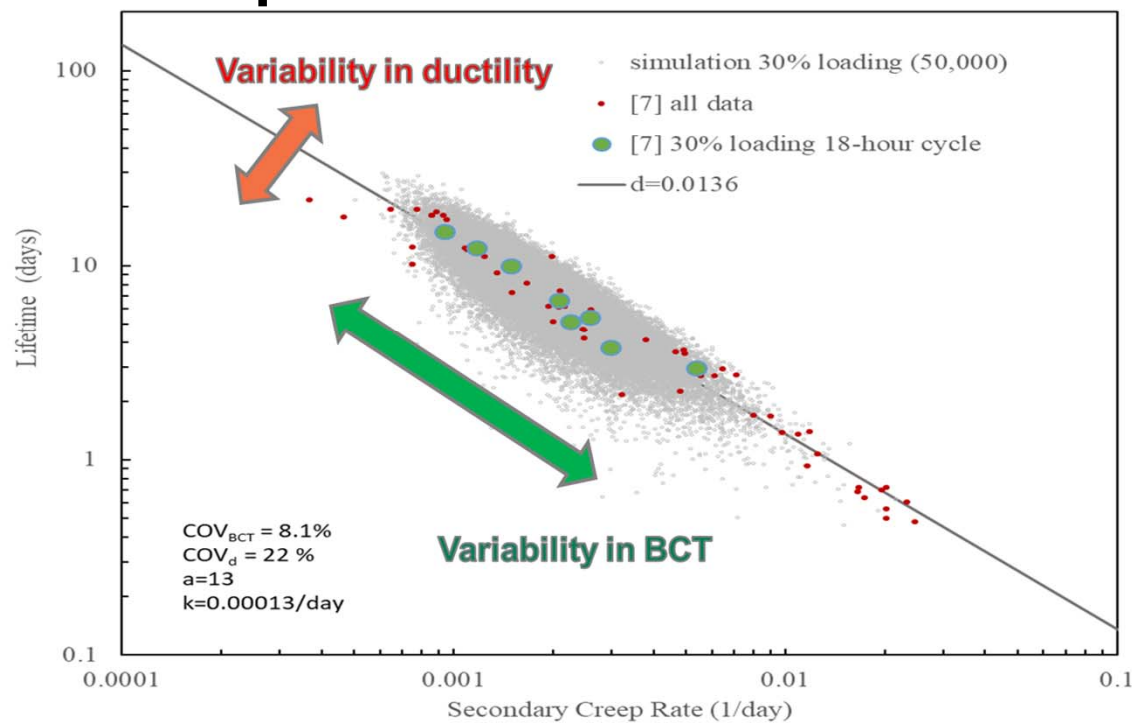


Stochastic Model vs Experiment

$$\bullet \text{ lifetime} = \frac{\text{ductility}}{|\text{creep rate}|}$$

lifetime

$$= k \text{ ductility} \left(\frac{\text{BCT}}{\text{load}} \right) e^{-a \left(\frac{\text{load}}{\text{BCT}} \right)}$$



Coffin, Wade, Hussain, *PaperCon* 2019

7.Hussain S., Coffin D. W., and Todoroki C. , "Investigating Creep in Structural Packaging" *Packaging Technology and Science*, 30(12):757-770 (2017).

Comparison of Two Boxes

- C-flute single wall boxes, RSC boxes
 - B1 has recycled medium
 - B2 has virgin medium
 - B1 used in previous study
- Both boxes have similar strength at 90% RH.

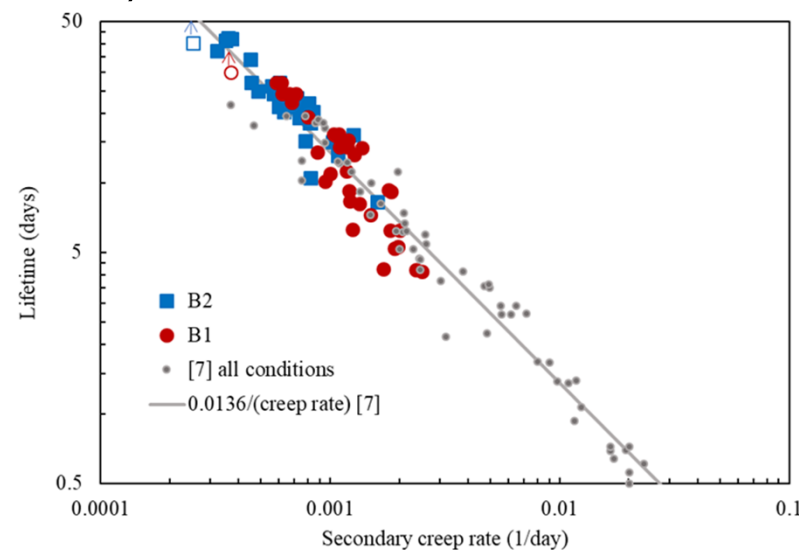


@ 50% RH	Box type B1	Box Type B2
Grammage, g/m ²	175/160/175	175/112/175
Lxwxh, mm	384 x 253 x 316	384 x 243 x 316
Caliper, mm	4.01 (1%)	4.04 (0.3%)
ECT, kN/m	6.48 (7.4%)	7.07 (7.8%)
4-pnt Bending	5.42 (6.0%)	6.73 (6.4%)
BCT, kN	3.26 (4.5 %)	3.24 (7.7 %)
McKee BCT simple, kN	2.71	2.95
McKee BCT Bending, kN	2.45	2.73

Lifetime Testing

- Creep tests at 4 °C, and 24-hour cycles of relative humidity between 50 and 90% RH.
- Dead load of 25% of BCT (Same load on both boxes)

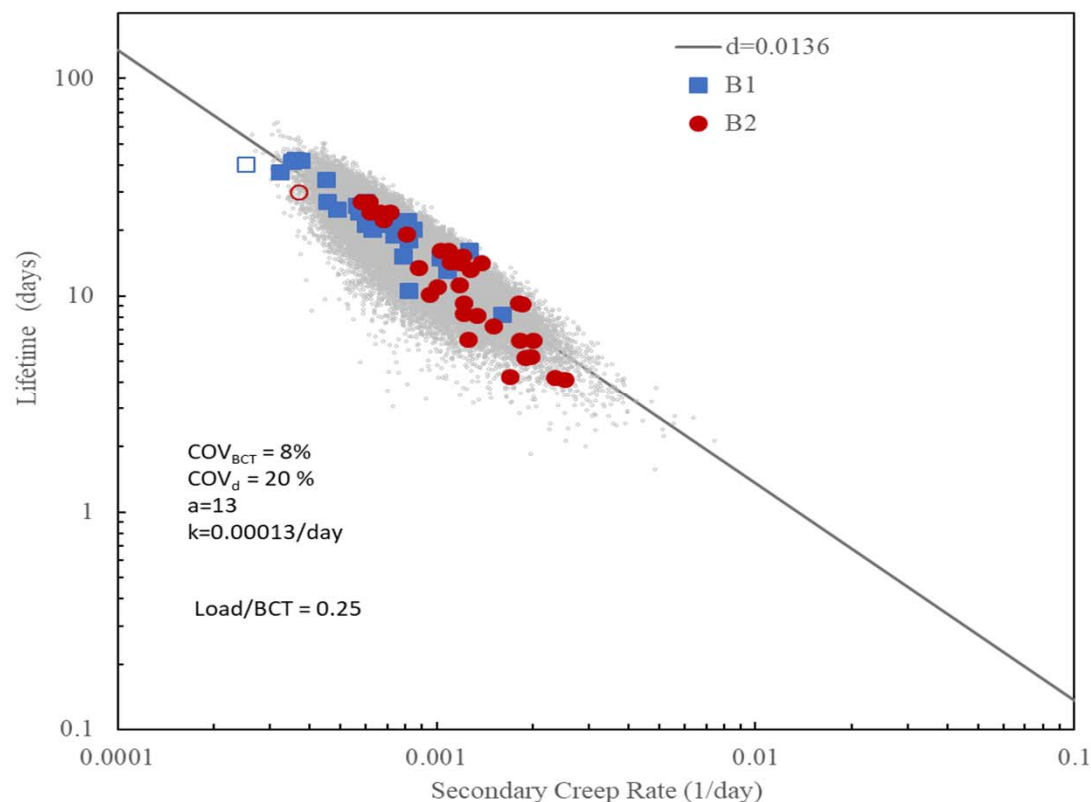
Box Type	n	Secondary Creep Rate 1/day	Lifetime , days	Ductility
B1	34	0.00126 (42%)	13.5 (56%)	0.0136 (25%)
B2	32	0.00070 (40%)	23.8 (38%)	0.0146 (16%)
Ref. [7]				0.0136 (22%)



Coffin, Wade, Hussain, *PaperCon* 2019

Comparison of Experiment to Simulation

- Both sets of results yield reasonable expectations using the parameters determined from previous study.
- Can not conclude that B1 and B2 exhibit different behavior as a population



Where do We go from here?

- Improve ductility of a box
- Reduce creep rate for a given load
- Reduce variability from box to box
- Creep testing of boxes to get significant results is costly
- Numerical modeling offers path to understanding

