Solar Kilns, Timber Quality & Cyclic Drying Schedules: The Importance of Mechano-Sorptive Strain

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Overview

- Solar kilns & cyclic drying schedules.
- Cyclic drying schedules & timber.
- Mechano-sorptive strain.
- A reason for solar drying being better than continuous drying.
- Quality in drying; stress-strain analysis.
- Assessment of continuous & cyclic schedules.

Acknowledgments

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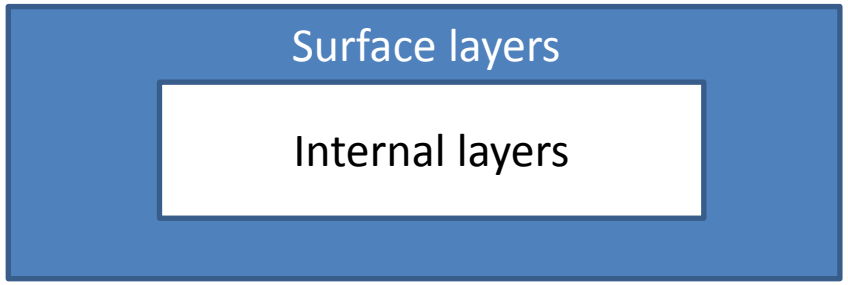
Solar Kilns & Cyclic Drying Schedules

- Daily patterns of sunshine & night, hot & cold, high & low relative humidity are a daily cycle.
- Timber, whether in the open air or inside a closed structure (a solar kiln) is exposed to this cycle of sun/night, hot/cold, humid/dry.
- Solar kilns give us control of the cycling.

Cyclic Drying Schedules & Timber

- Cycles of hot/cold, humid/dry affect the outside layers of the timber most immediately.
- Internal layers in board change later in time.



Summary: Mechano-sorptive Strain

- Humidity cycling up/down makes the moisture change up & down, particularly on the surfaces of the timber boards.
- The technical term for movement that occurs to reduce stress, which also
- Occurs more when the moisture content changes (in any direction, up & down).

One Reason Why Solar Drying is Better than Continuous Drying

- In timber drying, stresses are usually greatest on the board surfaces.
- Solar drying involves board surfaces drying & rewetting, so ms strain must be greater in cyclic drying than in continuous drying.
- More ms strain relaxes / decreases stresses.

Quality Measure

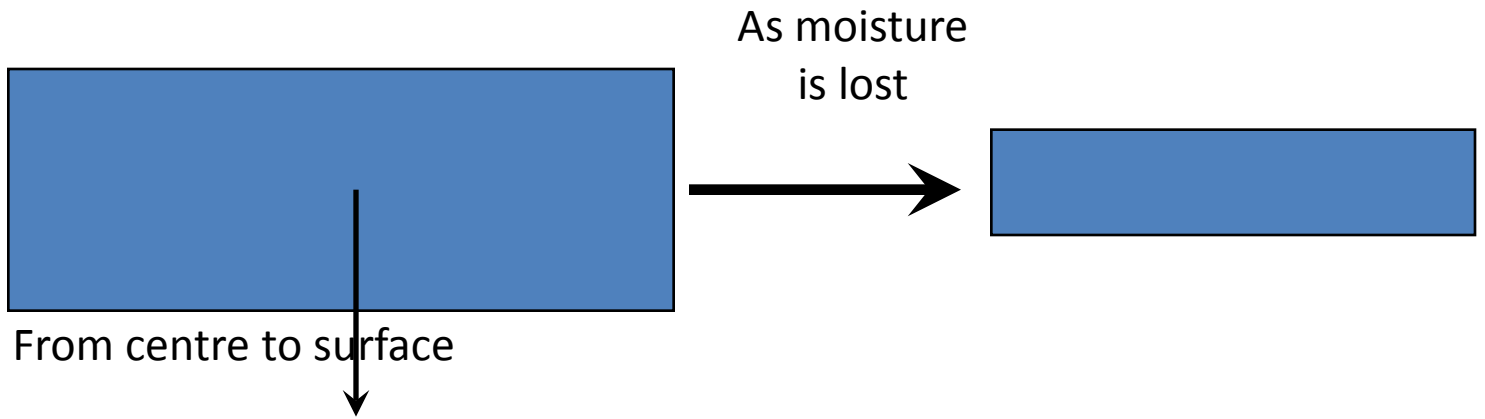
- Instantaneous stress proportional to instantaneous strain.
- Instantaneous stress causes cracks.
- Minimize the maximum absolute value of instantaneous strain (stress) to give best quality timber.

Theory: Timber Drying and the Development of Stresses and Strains

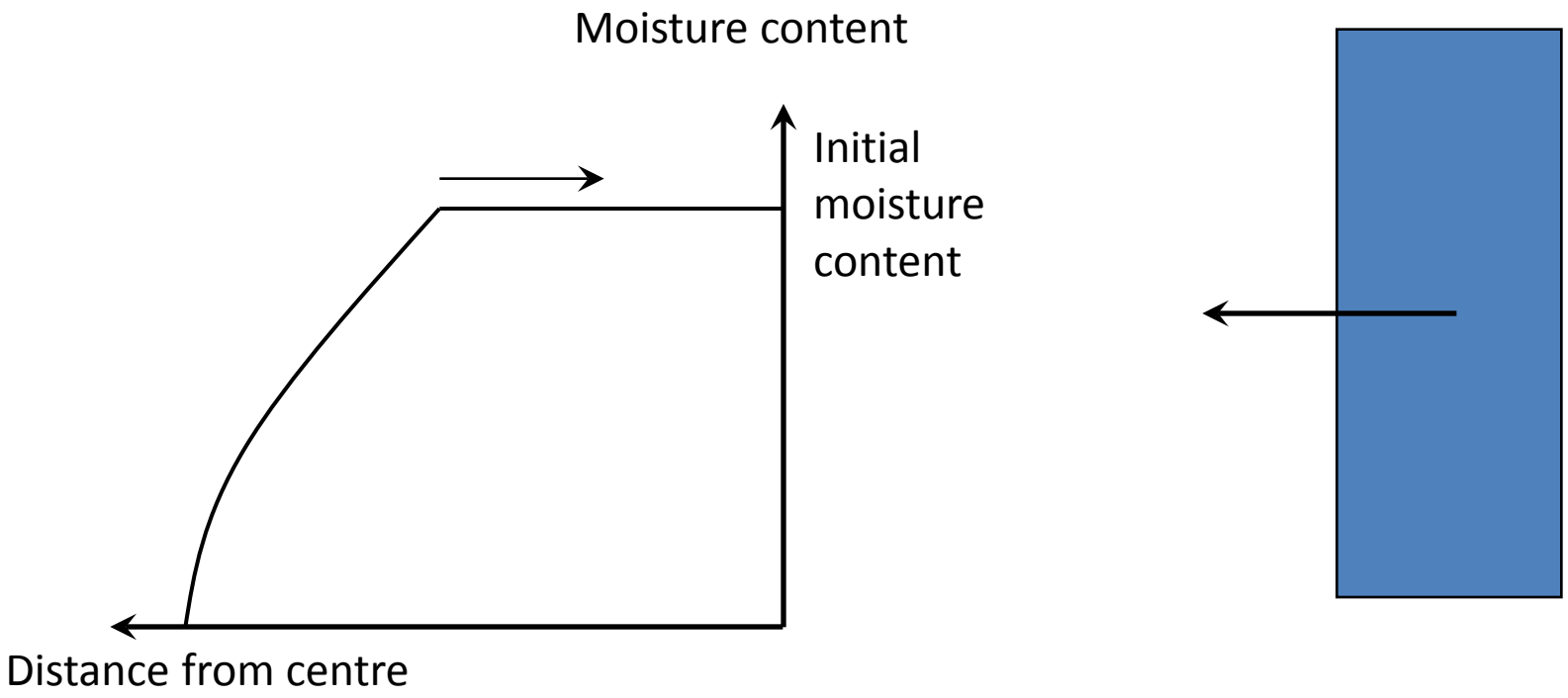
Minimizing Timber Degrade Due to Cracking

Ideal Timber Drying

- Shrinkage is inevitable; it would be good if this were uniform.

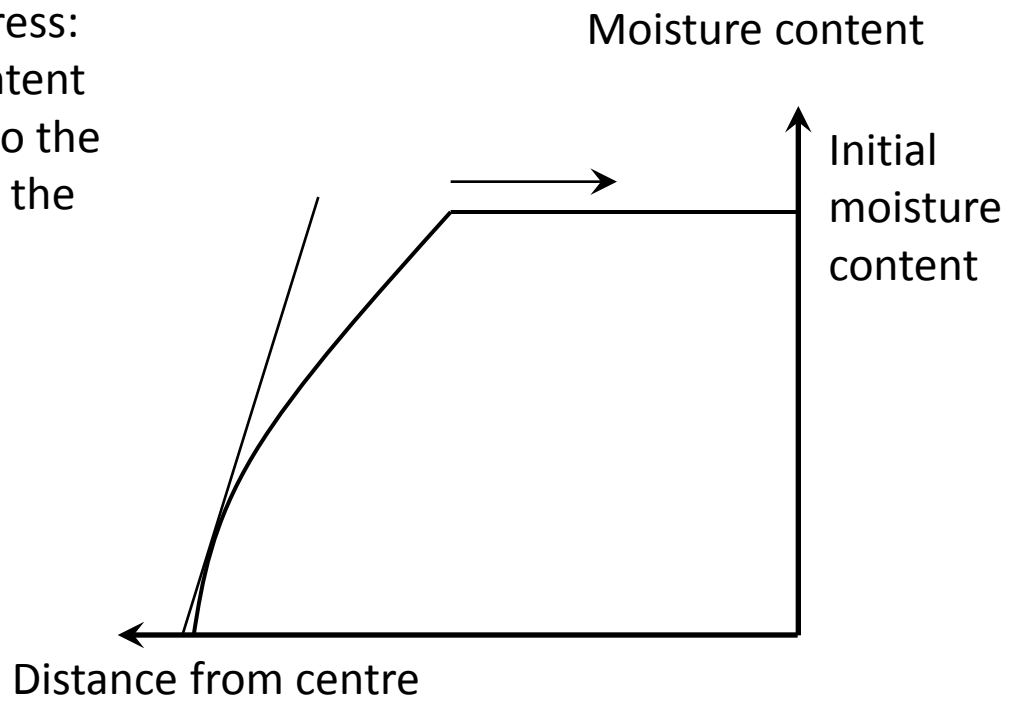


Timber Dries from the Outside In

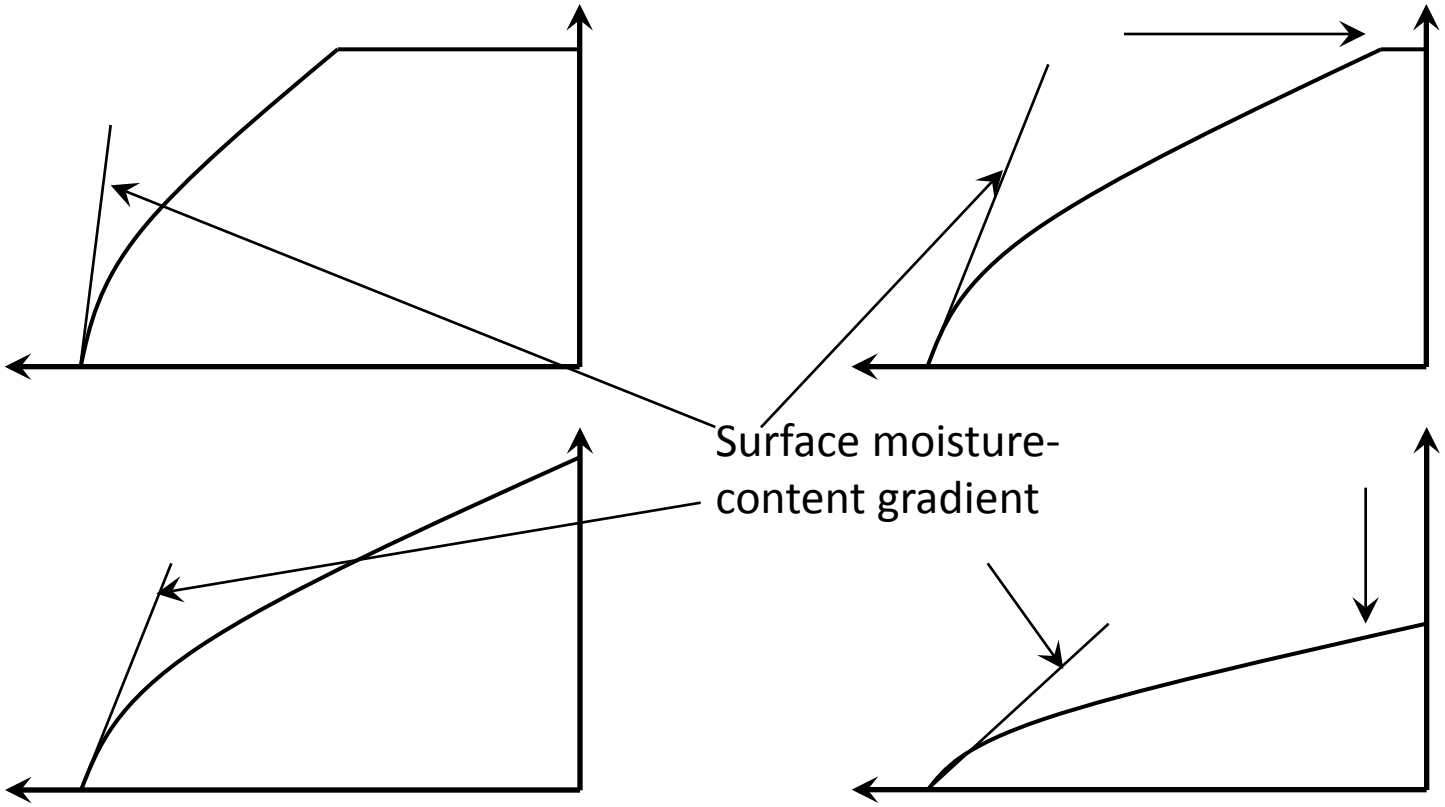


Driving Forces for Crack Development

The steeper the gradient in moisture content, the greater the stress: The steepest moisture- content gradient is at the surface, so the greatest stress initially is at the surface



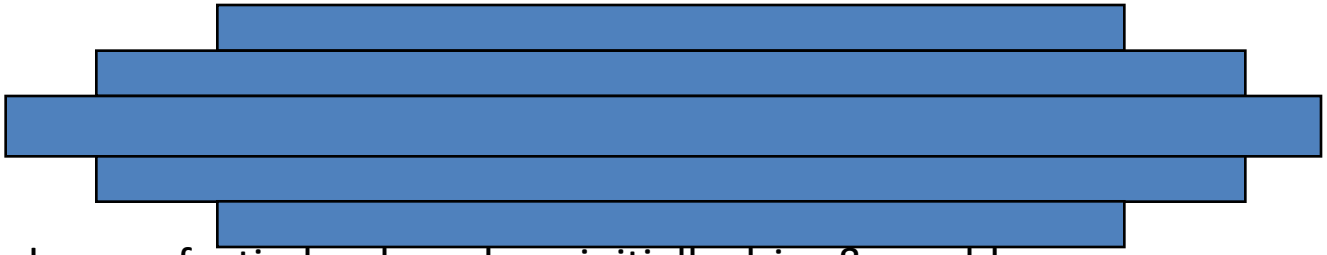
Moisture-Content Gradients During Drying



Development of Stresses

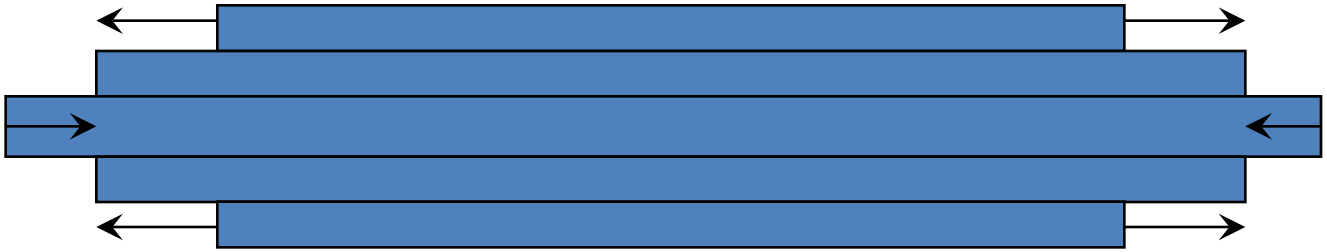
- Surface dries first, wants to shrink.
- Rest of material does not want to shrink.
- Tensile / tension stresses develop at the surface.

- If the timber were cut into layers that could move freely:

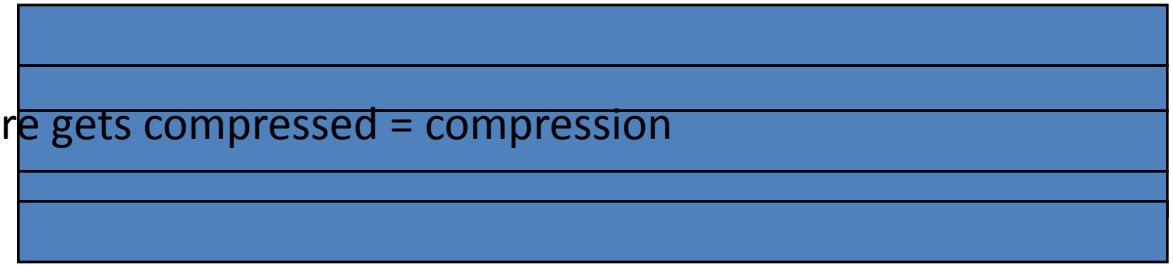


Outer layers of a timber board are initially drier & would shrink more than inner layers

Development of Stresses (cont.)



Outer layers get stretched = tension



Centre gets compressed = compression

Overall, no net stress

Minimizing Initial Stresses = Best Quality

- High moisture-content gradients at the surface tend to cause surface cracking.
- Minimize moisture-content gradients at the surface by gentle drying conditions initially, low wet-bulb depressions & low dry-bulb temperatures.

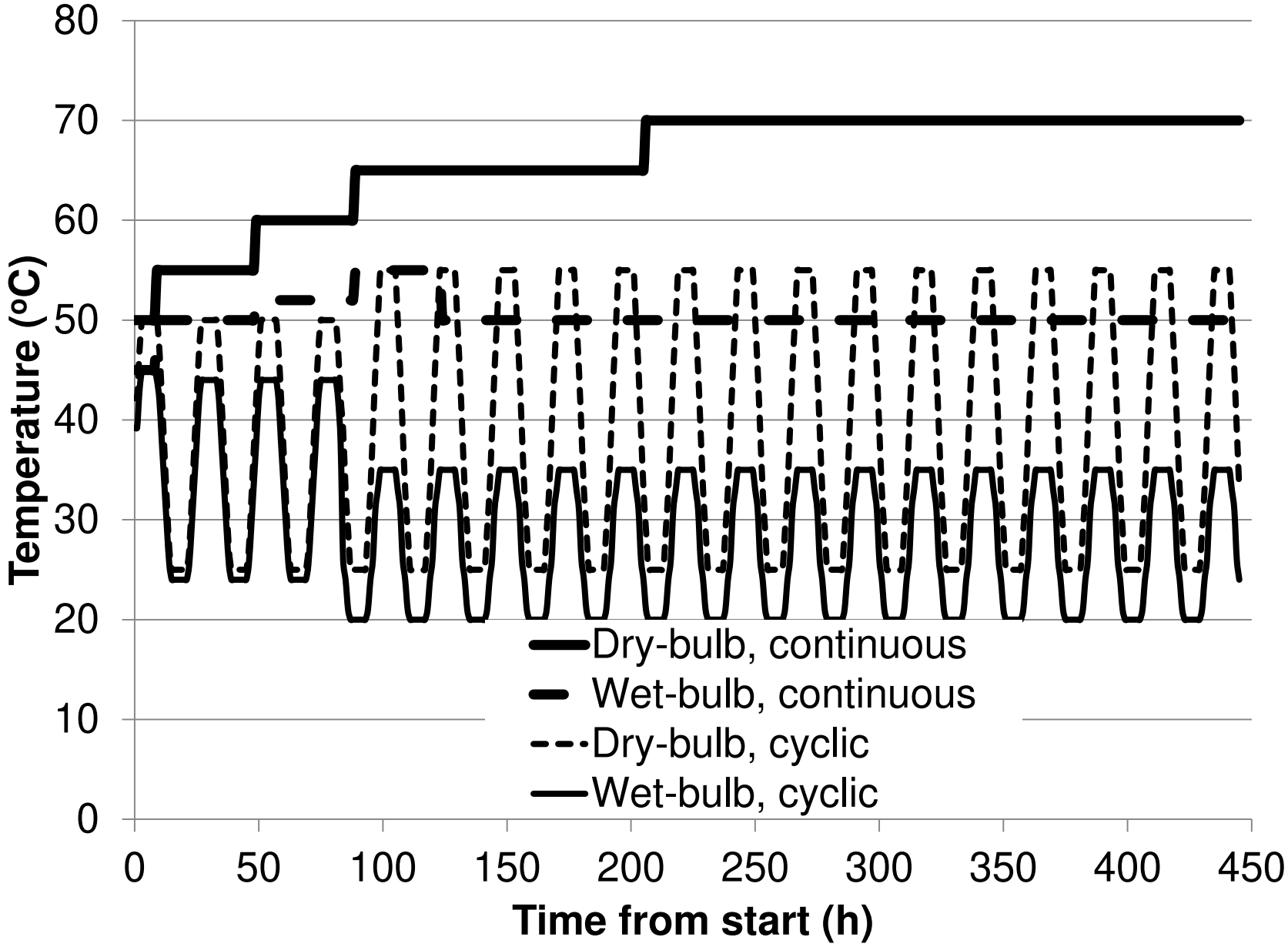
Internal Cracking / Checking

- If high moisture-content gradients at the surface do not cause surface cracking, then the tension at the surface causes the surface to stretch.
- If the surface dries without cracking and in a stretched condition, then when the inside shrinks, it may crack.

Use Stress-Strain Analysis to Assess Cyclic/Solar & Continuous Schedules

- Drying schedules.
- Quality assessment.
- Mechanosorptive & viscoelastic strains.
- Stresses & strains.
- Initial 48 hours.
- Behaviour of mechanosorptive strains: early stage & overall.

Drying Schedules



Quality Assessment

- Instantaneous strain < ±0.02, critical value (Oliver, 1991)
- Total strain = instantaneous strain + shrinkage strain + mechanosorptive strain + viscoelastic strain
- Instantaneous strain = Total strain - shrinkage strain - mechanosorptive strain - viscoelastic strain

Viscoelastic & Mechanosorptive Strains

- Mechanosorptive strain occurs to lower (relax) the instantaneous stress/strain
- Mechanosorptive strain >> viscoelastic strain
- Mechanosorptive strain affected by temperature, moisture content, stress & time.
- Viscoelastic strain affected by temperature, stress & time.

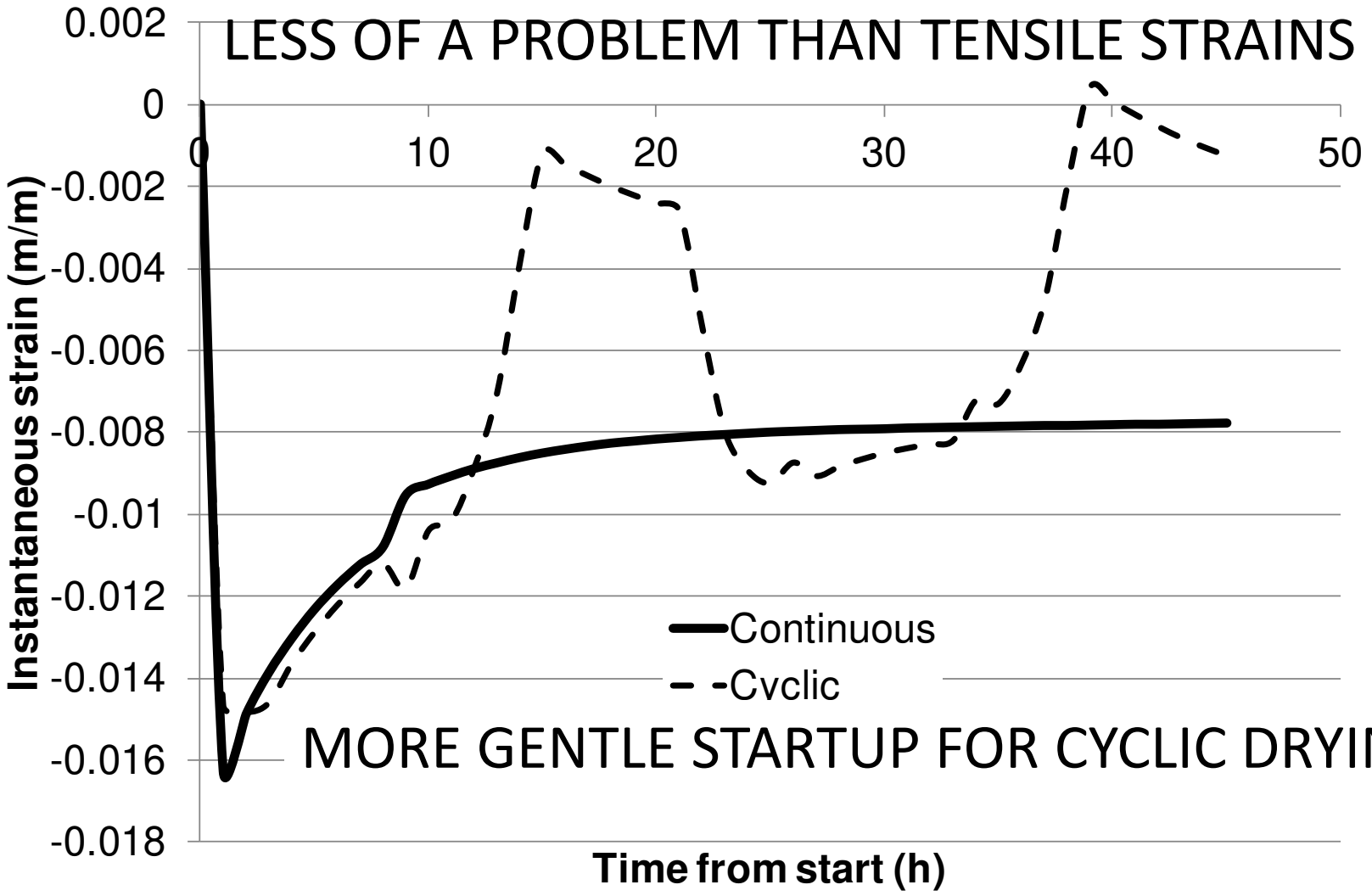
Stresses & Strains

- Tensile stresses = negative
- Instantaneous stress = modulus of elasticity x instantaneous strain
- Decreasing moisture-content gradients as drying proceeds, lower stresses & strains over time (but damage caused early becomes clearer)

Initial 48 Hours

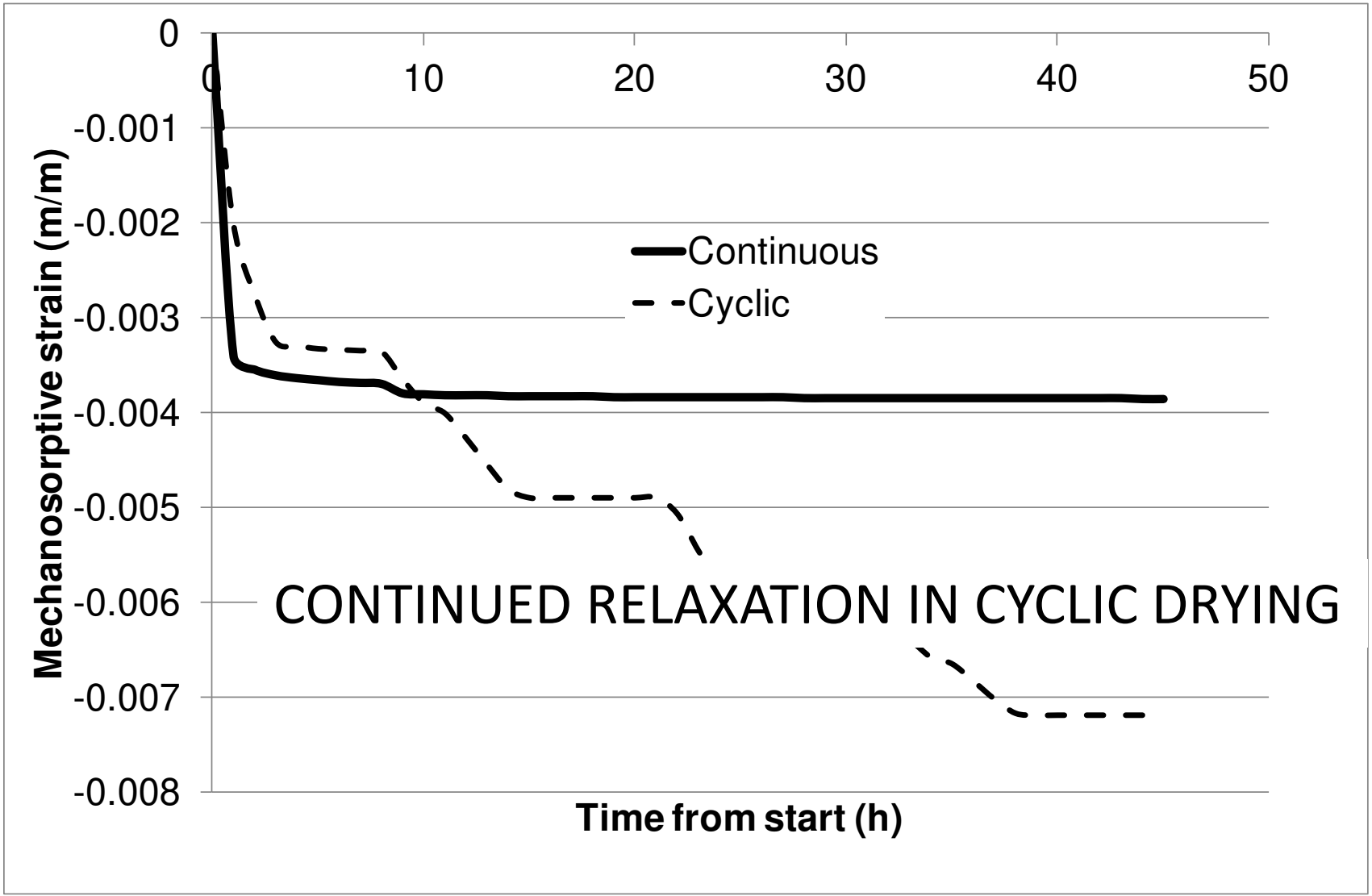
POSITIVE COMPRESSIVE STRAINS AT SURFACE

LESS OF A PROBLEM THAN TENSILE STRAINS

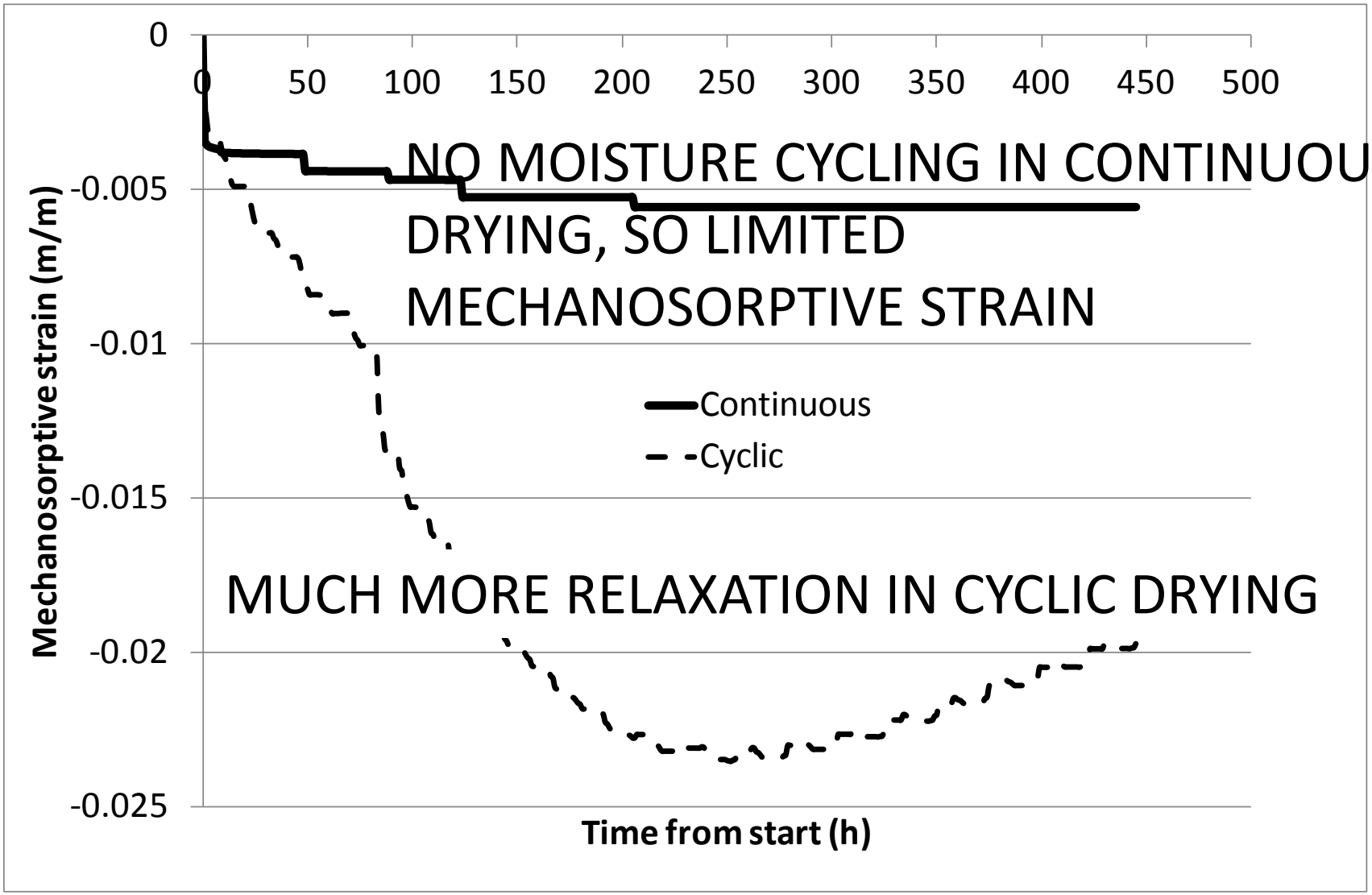


MORE GENTLE STARTUP FOR CYCLIC DRYING

Behaviour of Mechanosorptive Strains: Early Stages



Behaviour of Mechanosorptive Strains: Overall



Moisture Content Progression

- Continuous & cyclic drying both dry timber from 0.7 kg/kg (70%) to under 0.15 kg/kg (15%) in around two weeks.
- Cyclic drying gave better predicted quality.
- This theory & analysis apply equally to continuous & cyclic drying (the difference is in the schedule & what this schedule exploits). Applies to conventional kilns too.

Conclusions

- Cyclic schedules (solar kilns) give more gentle startups.
- More mechanosorptive strains in cyclic drying due to moisture cycling, more relaxation.
- Continued relaxation during drying period with cyclic schedules.
- Significant empirical evidence to support solar cyclic drying (Langrish & Keey, Herritsch et al., Plumptre & Thompson (UK), Greg Weir).

Links with Real Kiln Behaviour

- Mechano-sorptive strain = stress relaxation.
- MS strain relaxation is consistent with observations from Solarkilns.
- Explains at least part of the better timber quality frequently seen from solar kilns.
- Cyclic drying should also reduce case hardening – more research needed here.

More Research & Development, also

- Life-cycle analysis of solar kilns.
- Compare energy embodied in kiln materials with solar energy utilised by kiln.
- Answers question: are more complicated solar kiln designs better or worse overall, energy wise, compared with simple kiln designs.

Even More Research & Development

- This method has strong application for pre-drying collapsing eucalypts.
- In particular, there is potential relevance for the large problematic Australian plantation nitens & globulus estate.