“Museum Microclimates”
Copenhagen Conference
19-23 November 2007

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My thanks to all of the organizers for this conference.

My congratulations to all of the authors for the papers and posters presented.

You have addressed a lot of the issues I have wanted to look into at myself and I thank you for that.

It is everyone’s hope that we all come away from this conference with new insights and understanding.

There are several main themes that seem to be reoccurring:

- Passive environmental control of buildings and controlling the environment in historic buildings.

- Monitoring the environment of buildings and related spaces and exhibition cases.

- The effects of dust and pollution.

- The effects of light and biological considerations.

- The effects of environmental variation on the. structural stability of collections.

The objectives are:

Preservation of the collections

Preservation of the buildings

Enhanced visitor experience

Reduction in energy costs

Passive environmental control of buildings and controlling the environment in historic buildings

These are important areas because:

- Not every community can support the high cost of a HVAC retrofit even when it is possible.

- Energy cost are getting out of hand.

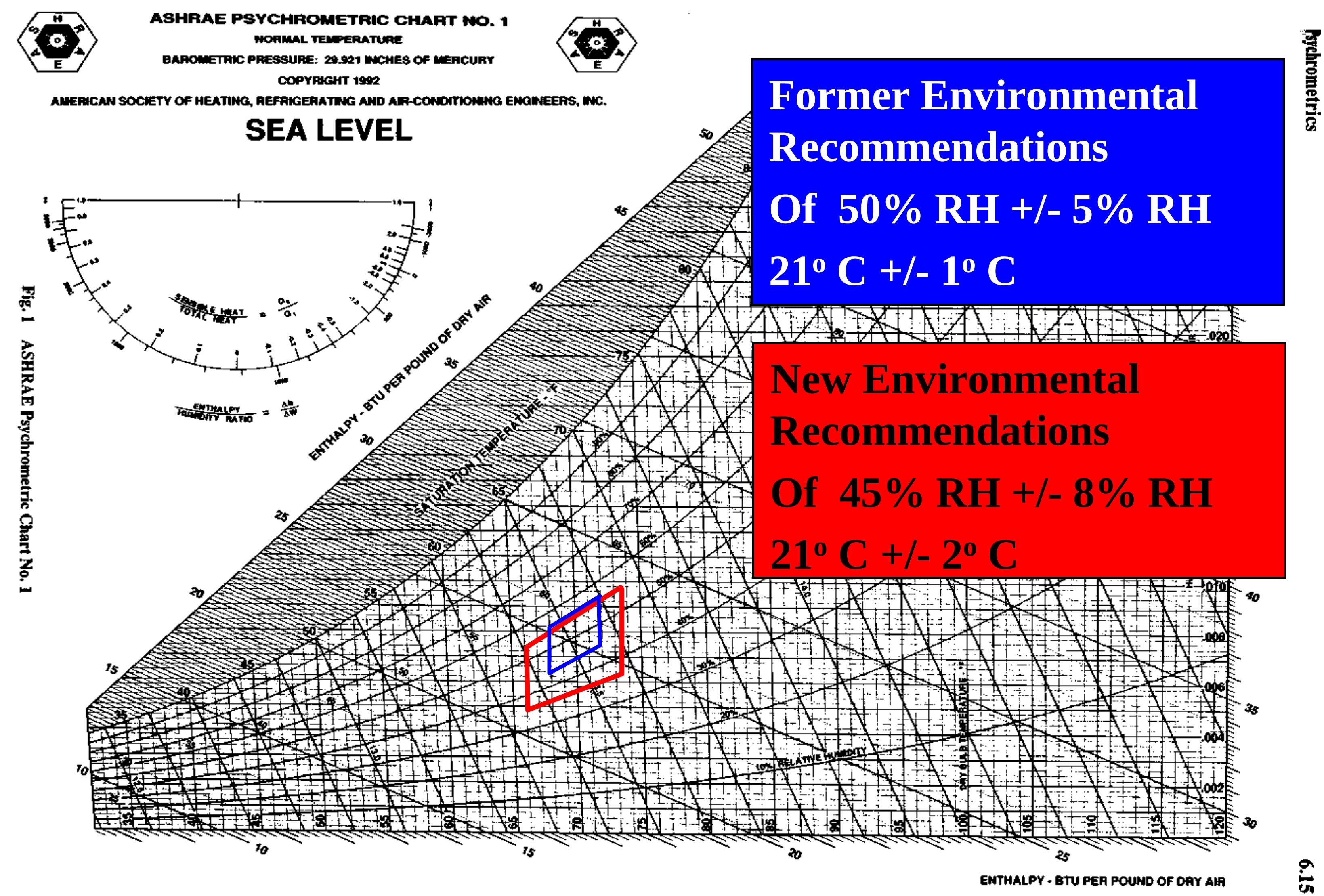
- When use inappropriately, induced moisture from HVAC systems can destroy buildings.

- The use of natural buffering and thermal mass can be very effective.

Sometimes however we lose sight of the effective management of existing HVAC systems.
We can use passive control recommendations to our benefit even in buildings with HVAC systems.

Papers in this conference discussed thermal inertia (mass) and buffered environments that help stabilize the environment. We can make these concepts work for even modern buildings.

In 2004 the Smithsonian adopted new environmental guidelines.



Former Environmental Recommendations

Of 50% RH +/- 5% RH

21º C +/- 1º C

New Environmental Recommendations

Of 45% RH +/- 8% RH

21º C +/- 2º C

Some of the energy conservation measures at the SI

Blue – Taking advantage of passive behavior

- **HVAC - running smaller/less boilers in the summer**
- **HVAC - secured/setback air handling equipment during unoccupied hours**
- **HVAC - raised chilled water supply set point; lowered boiler supply set point**
- **HVAC - secured outside air and exhaust during unoccupied hours**
- **HVAC - raised space temperature set point**
- **Hot water - lowered supply temperature; secured during unoccupied hours**
- **Power- secured non-essential pumps where appropriate**
- **Lighting – dimmed, secured, disconnected, removed exterior/interior lighting**
- **Lighting – rescheduled to shut off during unoccupied hours**
- **Lighting – installation of LED exit signs and occupancy sensors.**

The energy budget for the SI in FY 2006 was $32,800,000 US (over 600 buildings)

However by making even modest adjustments…

***"We saved $2.7 million in the last half of FY 2006, and about $1.5 million in the first quarter of FY 2007, mainly through changes in HVAC operations.**

The temperature and humidity guidelines help us because they are credible……and because they are broad and flexible enough to accommodate energy-saving strategies."

David Hauk, Chief Energy Management Branch
OFEO

This is about a 17% savings on an annual basis, about $6,000,000 US.

The effects of environmental variation on the collections

The big hole in much of our understanding revolves around the effects of the environment on structural damage.

For example, we constantly refer to the effects of temperature and relative humidity on the structural stability of collections.

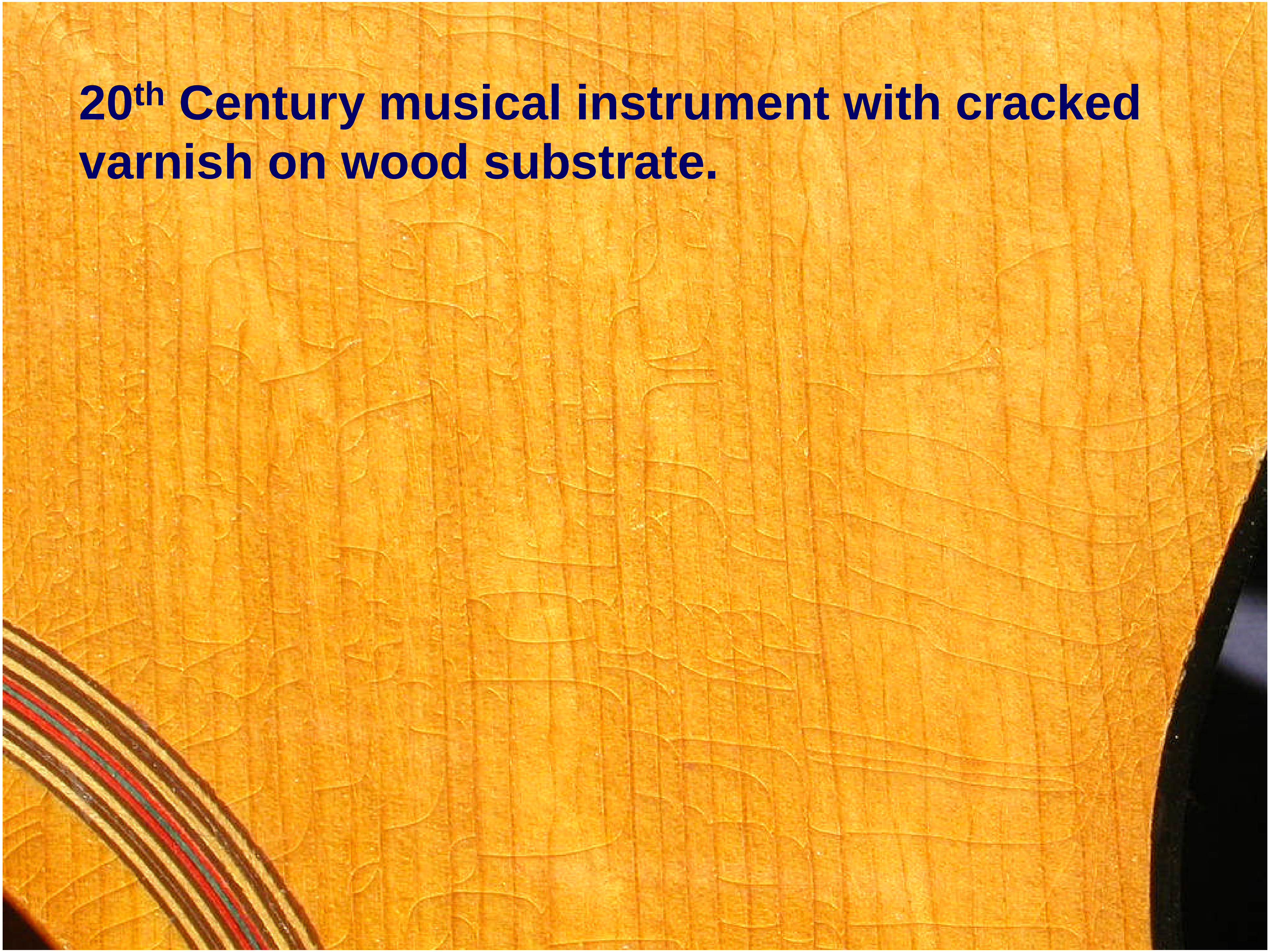
What’s the difference?

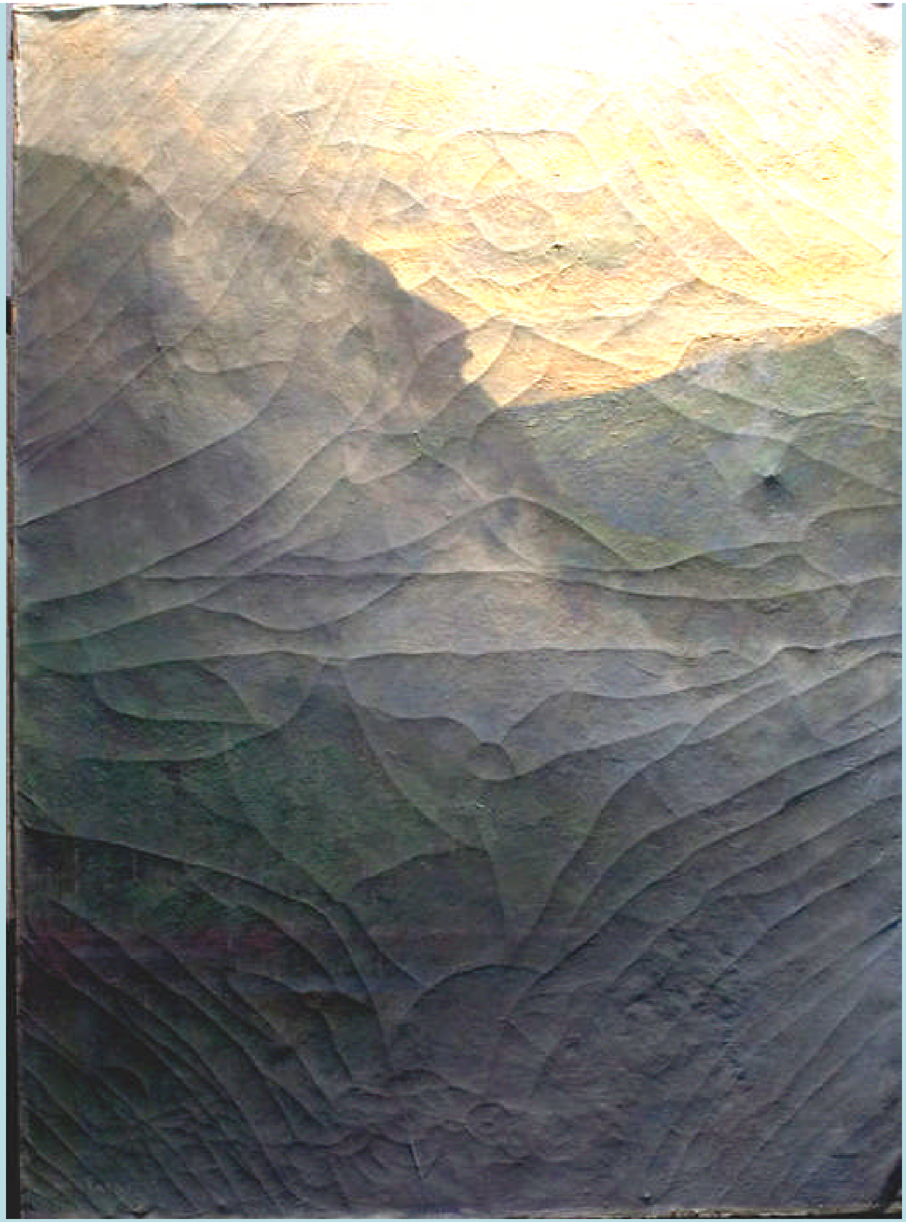
Historically there has been considerable confusion and controversy with regards to determining the correct temperature and relative humidity settings for museums and galleries.

Few were able to say with any certainty what caused damages in any specific object. There have certainly been anecdotal reports but rarely were specific details available.

For example, let's look at a few damaged objects.

20th Century musical instrument with cracked varnish on wood substrate.





George Parker, Untitled, (Lower Ausable Lake at Indian Head), American, 1911, 48in. x 35.5in. . (Photo by James Hamm and courtesy of the Adirondack Museum in Blue Mountain Lake, N.Y.)


19th century American landscape, oil on canvas.

20th century American abstract, oil and acrylic on canvas.
(Photo by James Hamm and courtesy of the owner)

All of the objects just seen were damaged by exposure to low temperatures (sub zero) and RH played no role at all.

The reason these object were damaged by low temperature is because all oil, alkyd and acrylic paints have low glass transition temperatures.
If the ambient temperature falls enough below the glass transition temperature, the paint layers can crack.

Let's try again

Detail, 20th century English Abstract, oil on canvas.

(Photograph courtesy of Richard Saltoun and taken by Steve Gayler)

Detail, 20th Century Italian, Photograph courtesy of Matteo Doria Rossi

The 1st painting shown was damaged by rolling and neither temperature or relative humidity played any role in the damage.

The reason the damages are so extensive with interlayer cleavage was that zinc oxide was mixed with the other pigments in the oil. Zinc is notorious for cracking and delaminating.
(Research on the mechanical properties of artists paints at the SI, MCI)

We certainly need to be able to accurately assess the effects to temperature and RH Independently.

What we need is a …

Better estimate of impact

Agnes Brokerhof

Taking the next step

Two case studies.

Warm Feet and Cold Art: Is This the Solution? Polychrome Wooden Ecclesiastical Art- Climate and Dimensional Change.

Tone M. Olstad and Annika Haugen

This paper and those like it are critically important since they address very real problems. Let’s try to answer some of those questions.

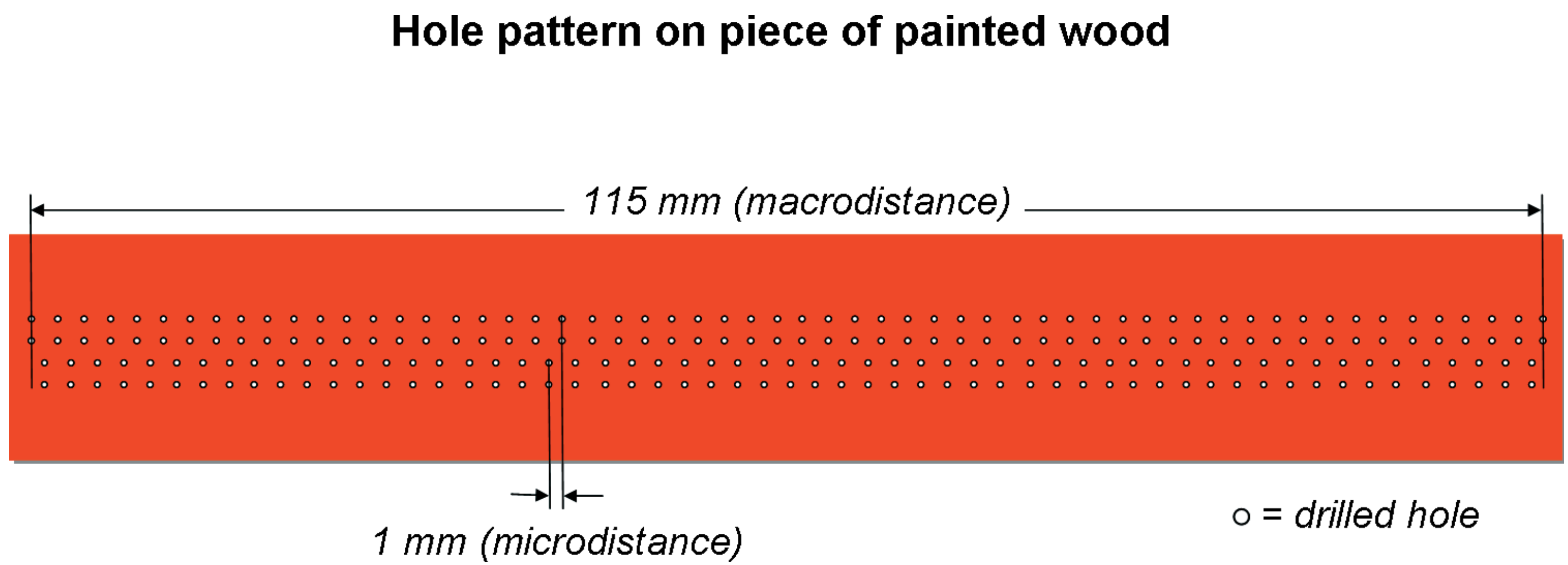


Figure 1. The macro area is 115 mm. It is divided into micro areas. Each micro area is 1 mm and is marked by drilled holes (white dots) in the paint. Two parallel lines of 57 and 58 pairs of holes were drilled. A micro area is the distance between the lines which are formed between the middle of two pairs of drilled holes (white dots). One micro area is the distance between the two black arrows on the figure.

At the end of their paper Tone M. Olstad and Annika Haugen asked the following questions.

FUTURE WORK

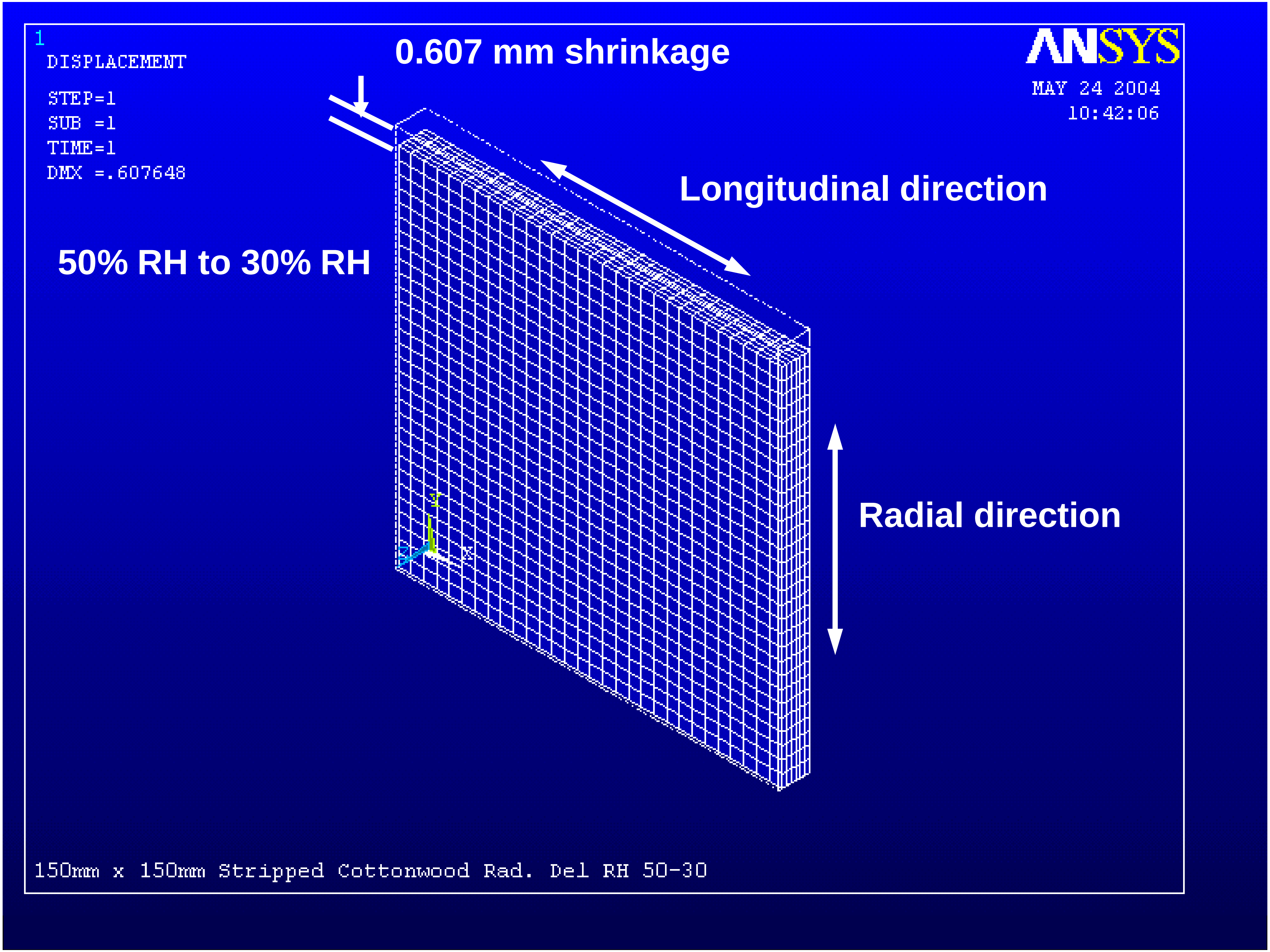
In the future the following questions need to be answered:

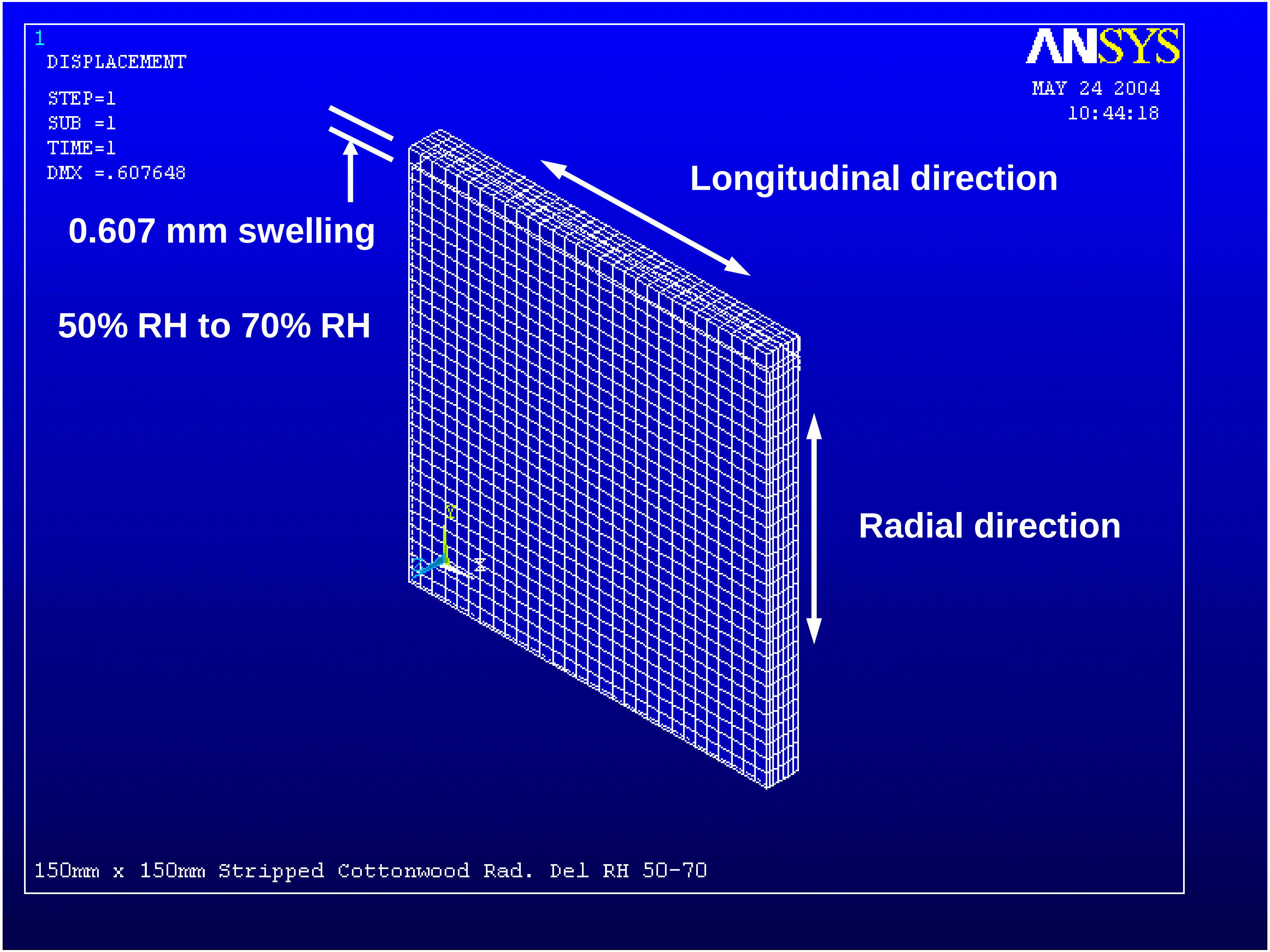
- Is damage in the paint layer related to micro movements in the wood caused by fluctuations in climate?
- Are visible damages in the paint layers related to intermittent heating?
- Is it significant if the values of RH or T rise or fall?

Measuring deformation is important when discussing the effects of RH on Wooden Polychrome Art. But deformation alone will not be sufficient to determine the damage mechanism or the range of RH causing the damage.

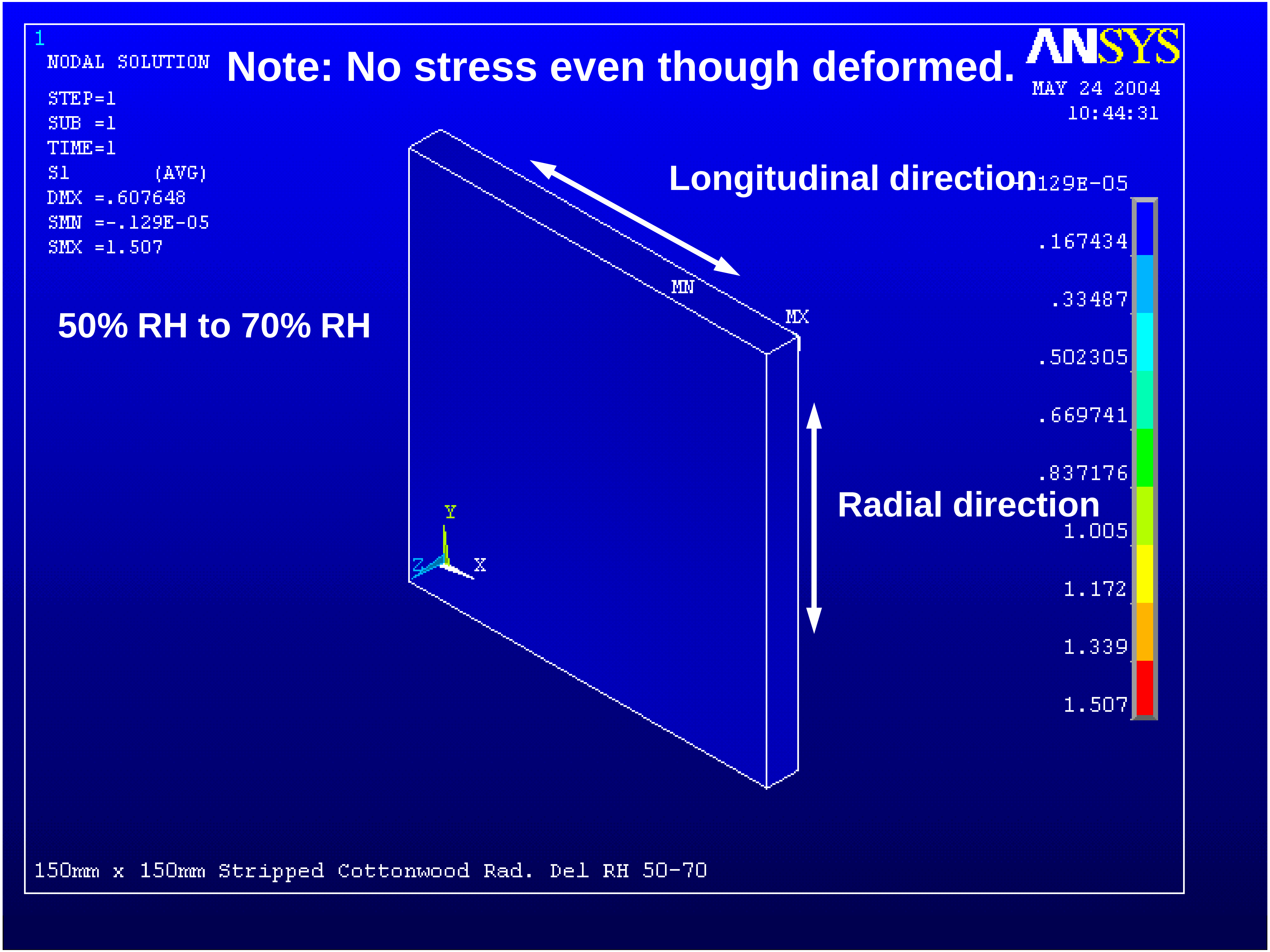
It is necessary to know the mechanical properties of the materials and have a method to model the internal stresses developed by deformation.

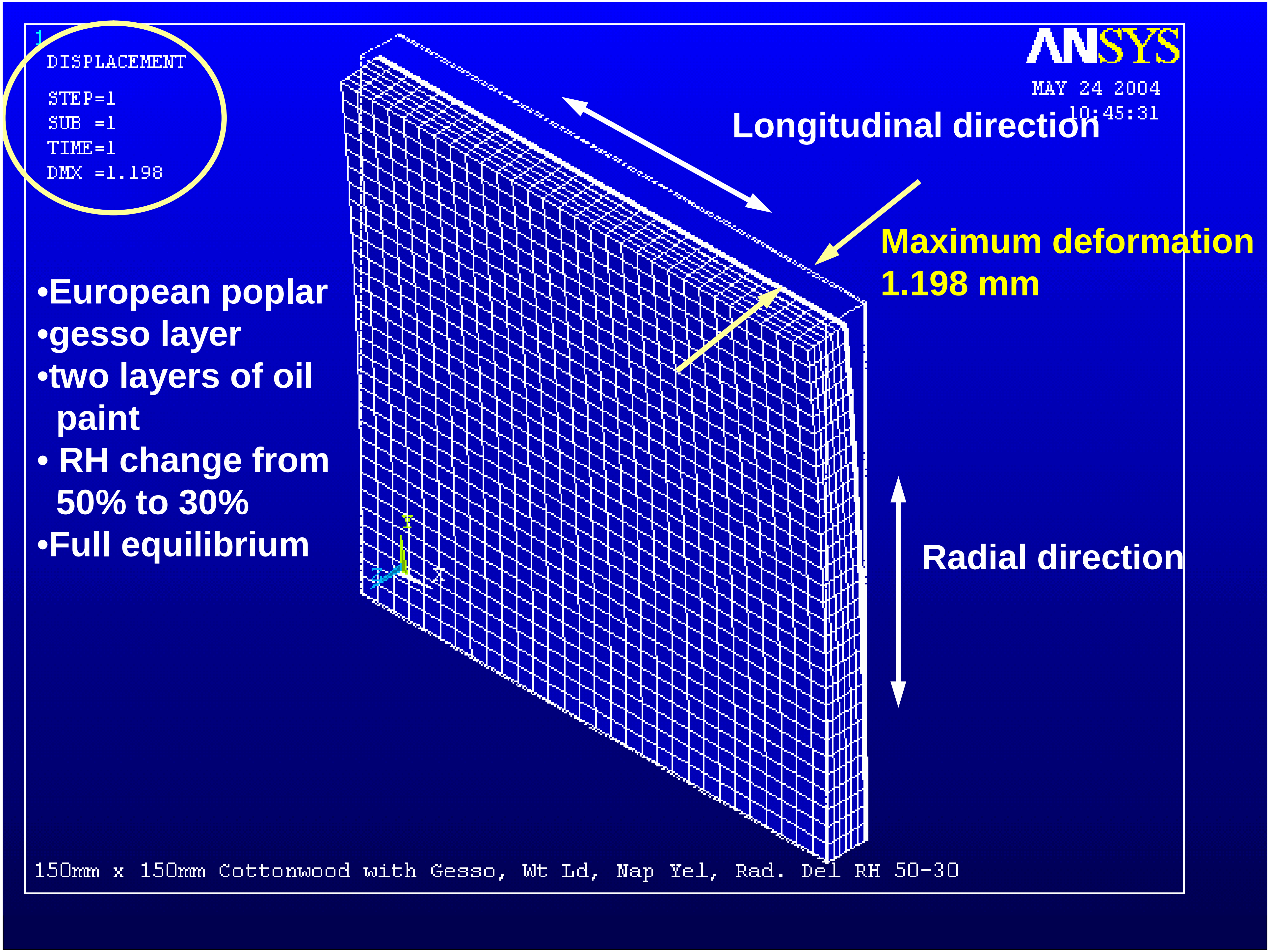
For example…….

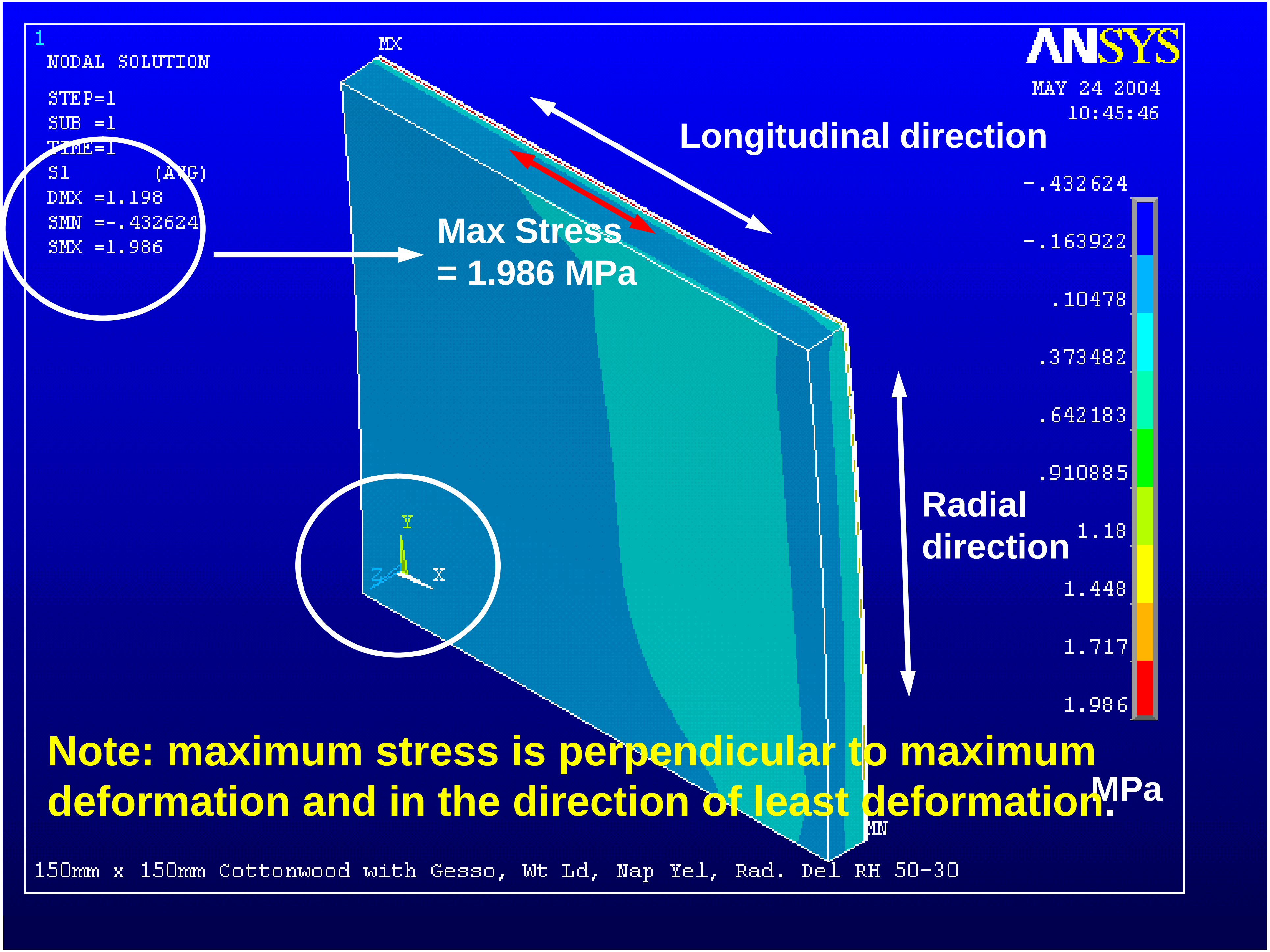

1
DISPLACEMENT
STEP=1
SUB =1
TIME=1
DMX =.607648
0.607 mm shrinkage
ANSYS
MAY 24 2004
10:42:06
Longitudinal direction
50% RH to 30% RH
Radial direction
Y
X
150mm x 150mm Stripped Cottonwood Rad. Del RH 50-30



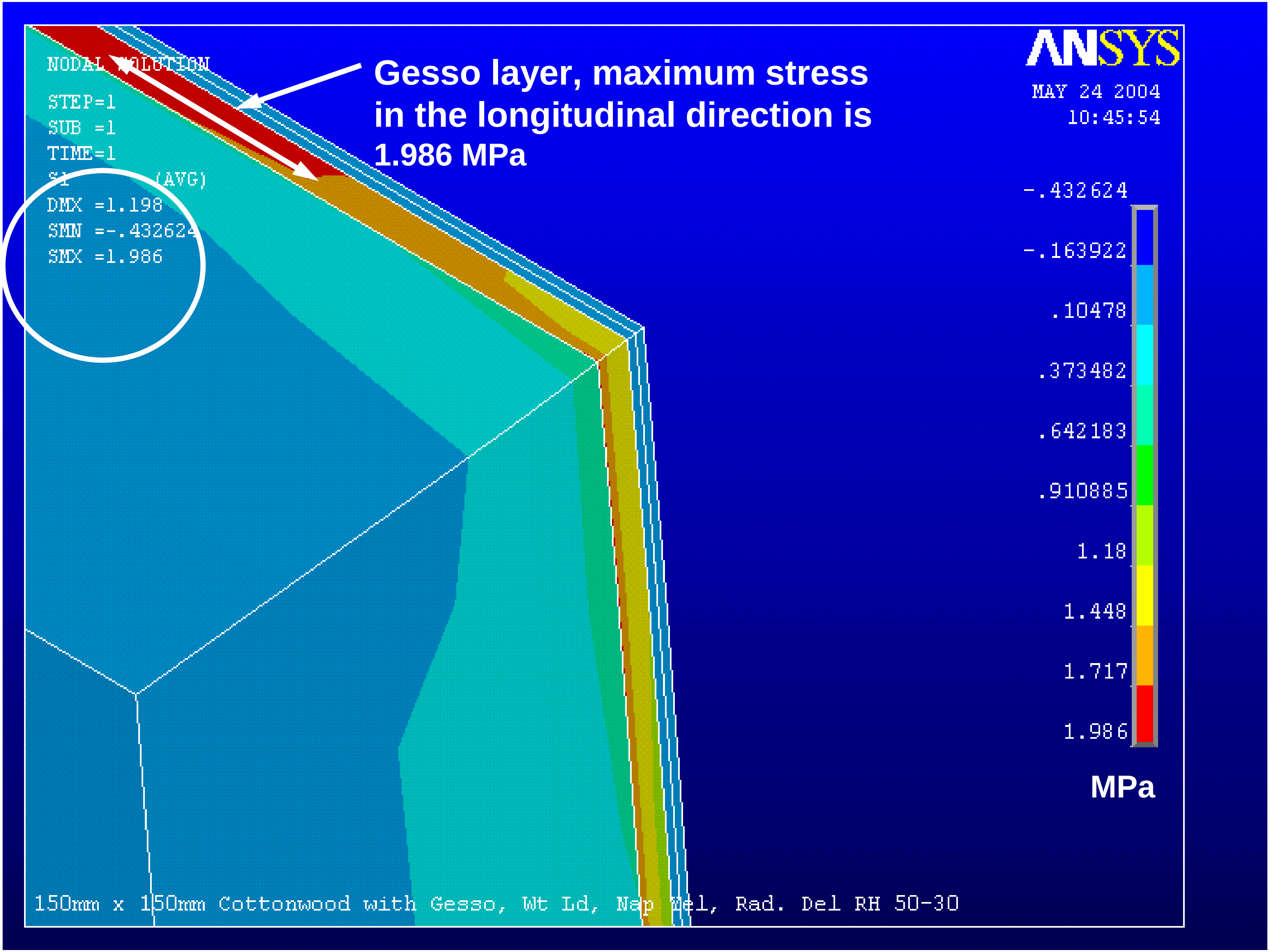
1
DISPLACEMENT
STEP=1
SUB =1
TIME=1
DMX =.607648
ANSYS
MAY 24 2004
10:44:18
0.607 mm swelling
50% RH to 70% RH
Longitudinal direction
Radial direction
150mm x 150mm Stripped Cottonwood Rad. Del RH 50-70


1
NODAL SOLUTION
Note: No stress even though deformed.
ANSYS
MAY 24 2004
10:44:31
STEP=1
SUB =1
TIME=1
S1 (AVG)
DMX =.607648
SMN =-.129E-05
SMX =1.507
Longitudinal direction
-.129E-05
.167434
.33487
.502305
.669741
.837176
1.005
1.172
1.339
1.507
MN
MX
50% RH to 70% RH
Radial direction
Y
Z
X
150mm x 150mm Stripped Cottonwood Rad. Del RH 50-70

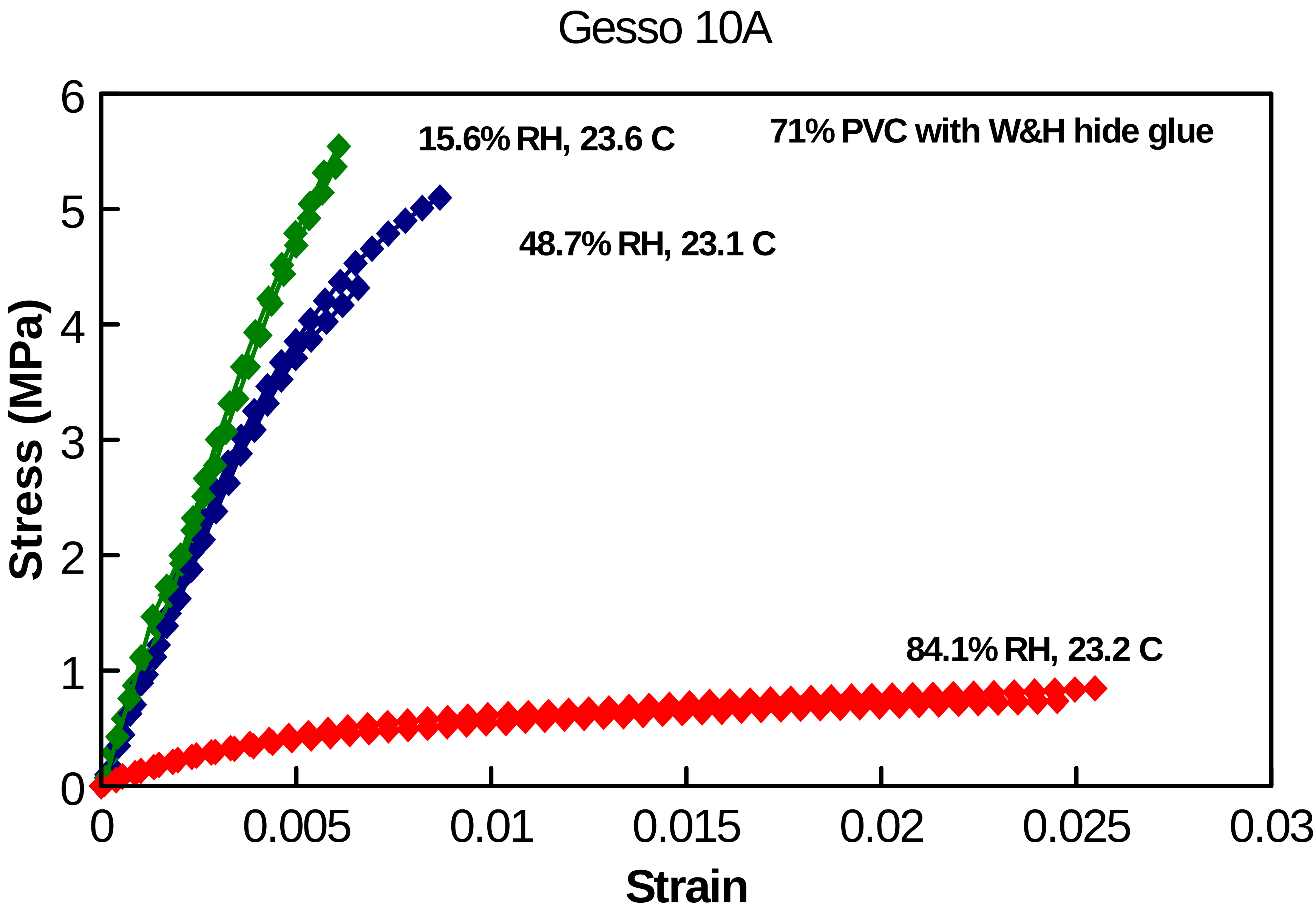

1
DISPLACEMENT
STEP=1
SUB =1
TIME=1
DMX =1.198
ANSYS
MAY 24 2004
10:45:31
Longitudinal direction
Maximum deformation
1.198 mm
•European poplar
•gesso layer
•two layers of oil paint
• RH change from 50% to 30%
•Full equilibrium
Radial direction
Y
Z
X
150mm x 150mm Cottonwood with Gesso, Wt Ld, Nap Yel, Rad. Del RH 50-30



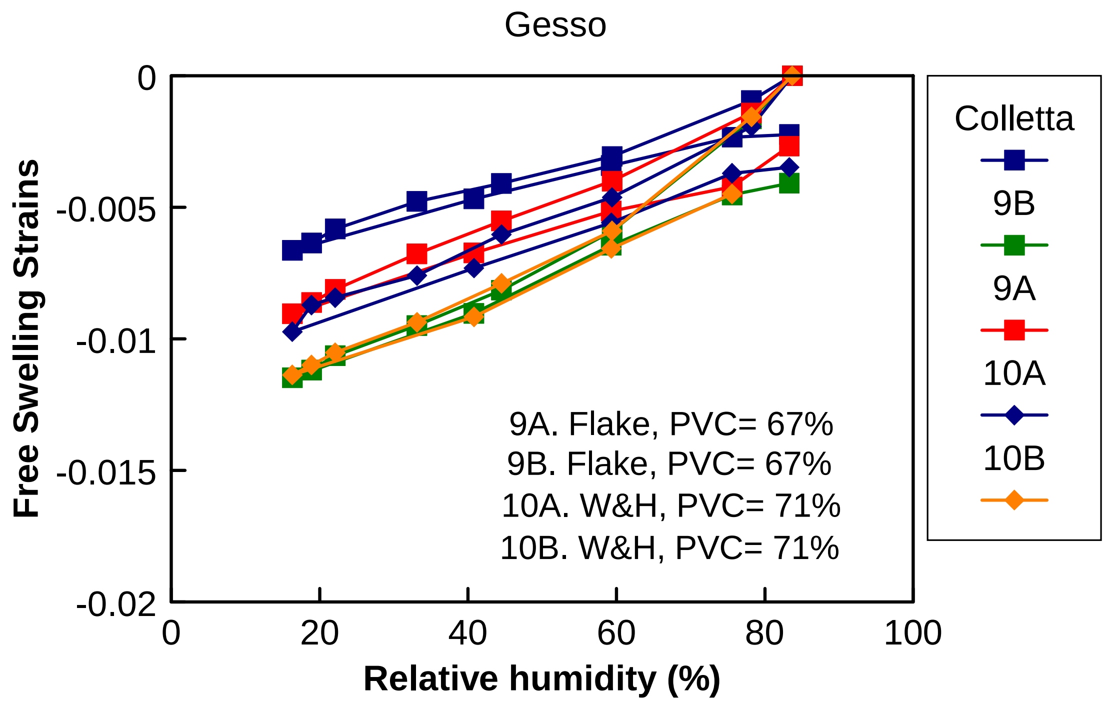
1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
S1 (AVG)
DMX =1.198
SMN =-.432624
SMX =1.986
MX
ANSYS
MAY 24 2004
10:45:46
Longitudinal direction
Max Stress
= 1.986 MPa
-.432624
-.163922
.10478
.373482
.642183
.910885
1.18
1.448
1.717
1.986
Radial
direction
Y
X
Z
MPa
MN
Note: maximum stress is perpendicular to maximum deformation and in the direction of least deformation.
150mm x 150mm Cottonwood with Gesso, Wt Ld, Nap Yel, Rad. Del RH 50-30

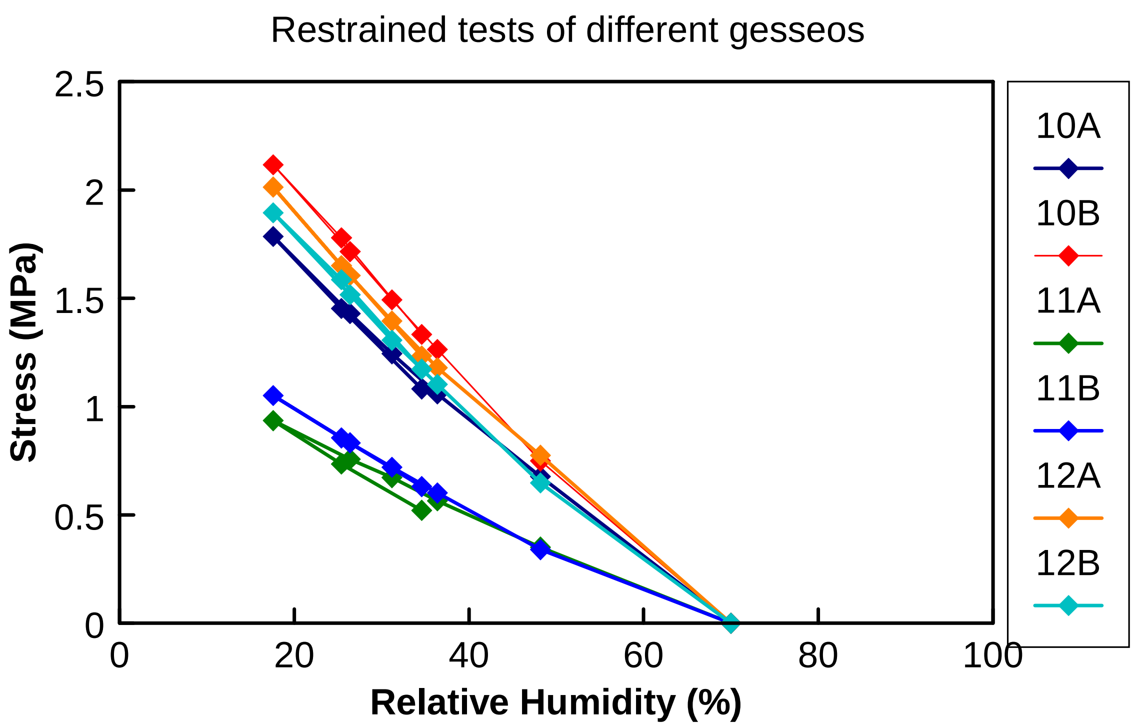

Gesso layer, maximum stress in the longitudinal direction is 1.986 MPa
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
S1 (AVG)
DMX =1.198
SMN =-.432624
SMX =1.986
ANSYS
MAY 24 2004
10:45:54
-.432624
-.163922
.10478
.373482
.642183
.910885
1.18
1.448
1.717
1.986
MPa
150mm x 150mm Cottonwood with Gesso, Wt Ld, Nap Del, Rad. Del RH 50-30

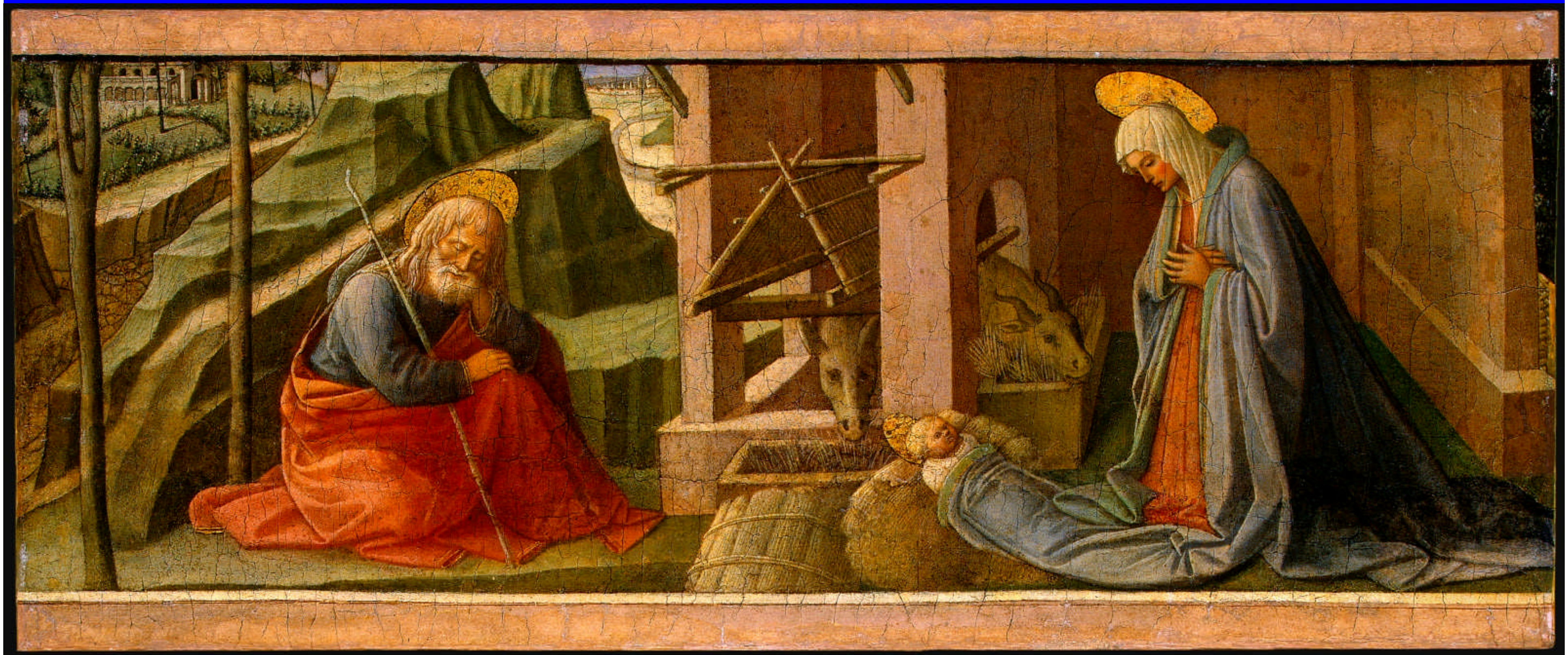
It is now possible to compare actual material test data to the computer model results.



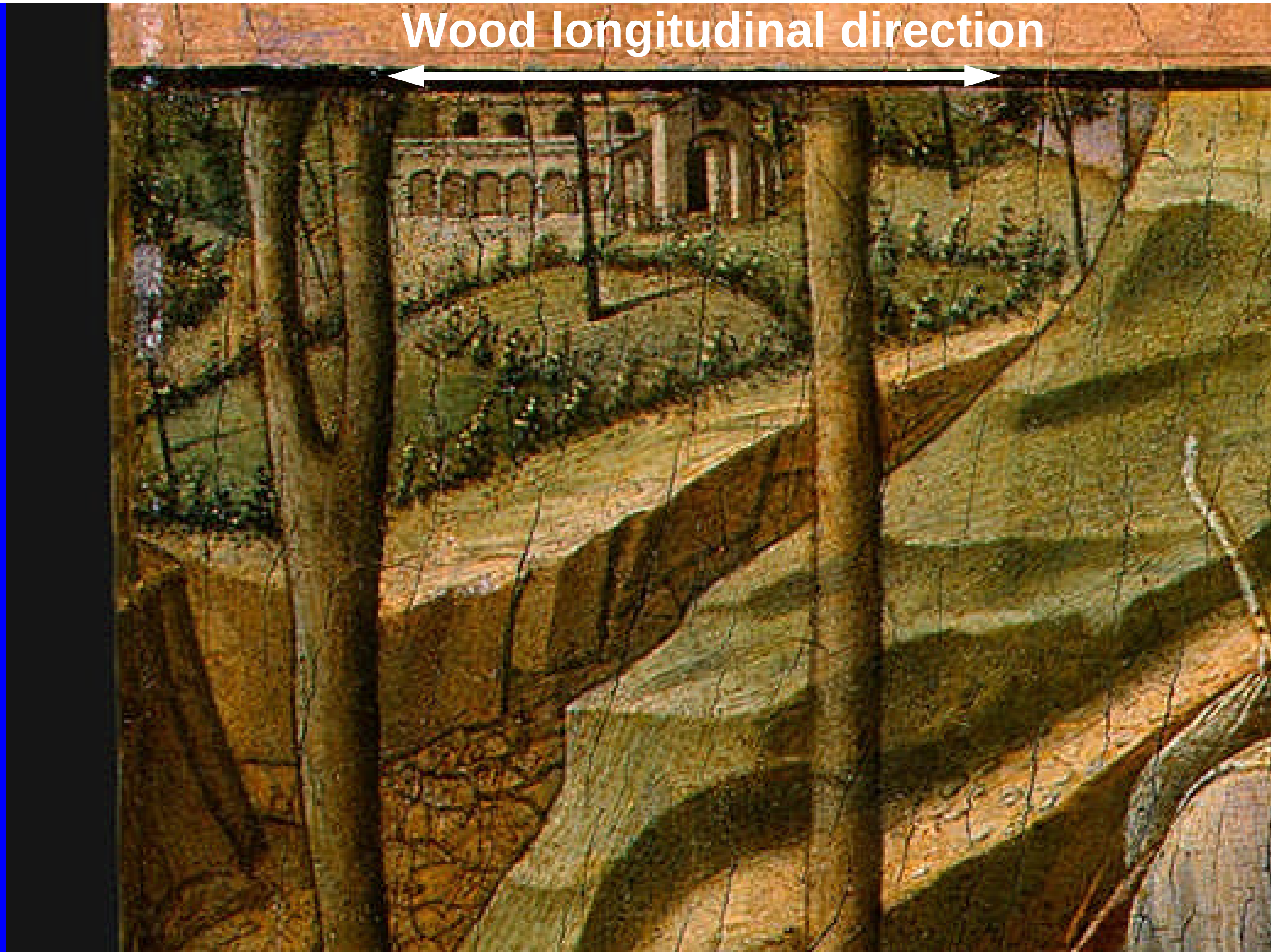
Gesso 10A
71% PVC with W&H hide glue
15.6% RH, 23.6 C
48.7% RH, 23.1 C
84.1% RH, 23.2 C
Stress (MPa)
0
1
2
3
4
5
6
0
0.005
0.01
0.015
0.02
0.025
0.03
Strain


Gesso
Free Swelling Strains
Relative humidity (%)
0
-0.005
-0.01
-0.015
-0.02
0
20
40
60
80
100
9A. Flake, PVC= 67%
9B. Flake, PVC= 67%
10A. W&H, PVC= 71%
10B. W&H, PVC= 71%
Colletta
9B
9A
10A
10B


Restrained tests of different gesseos
Stress (MPa)
Relative Humidity (%)
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
10A
10B
11A
11B
12A
12B



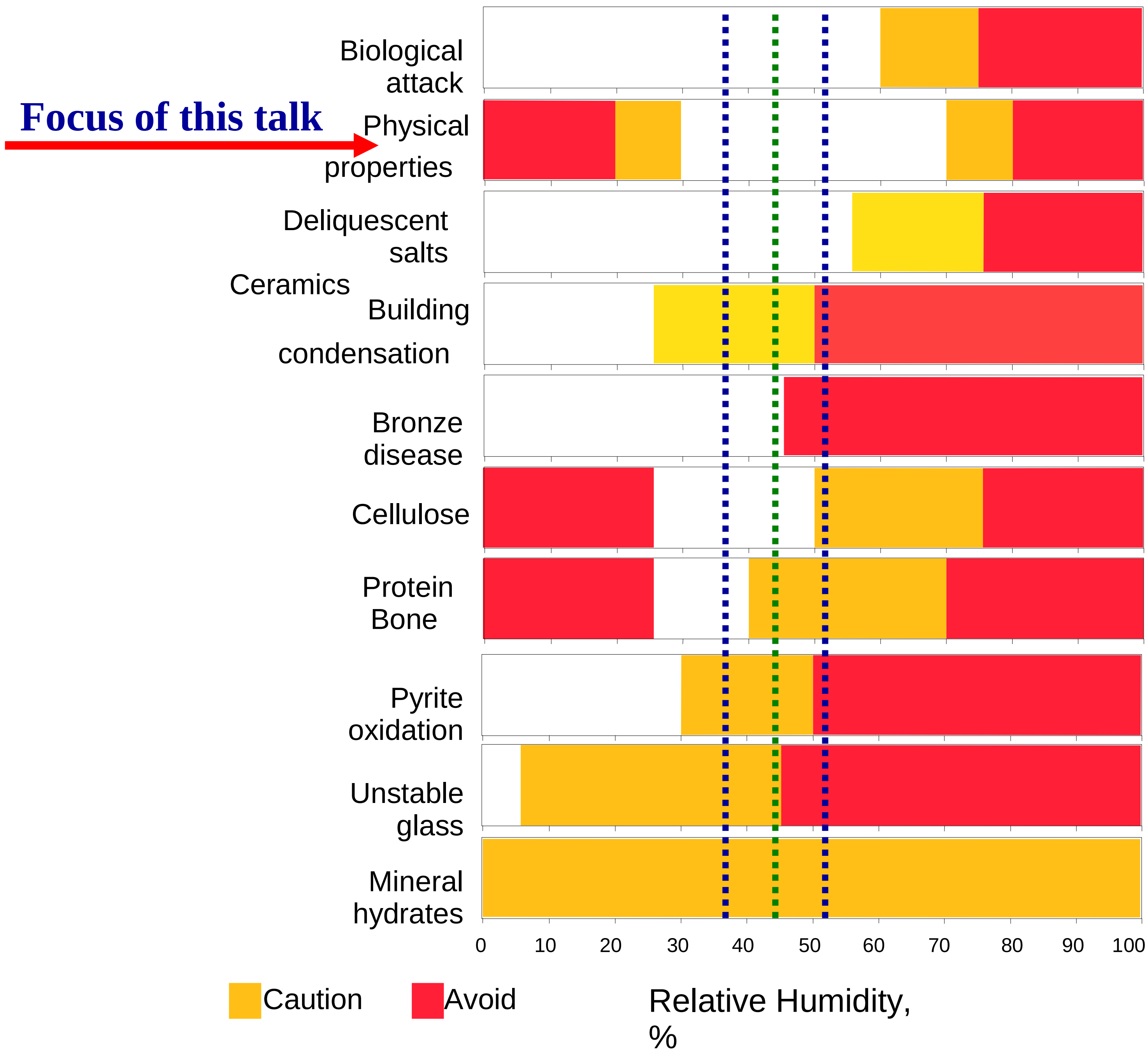
Fra Lippo Lippi and workshop, Florentine, c. 1406-1469, The Nativity, probably c 1445, oil and tempera (?) on panel, 9 1/8 in. x 21 ¾ in. (23.2 x 55.3 cm), Samuel H. Kress Collection, 1939.1.279. (courtesy of the National Gallery of Art, Washington, D.C.)



All of the cracks originated in the gesso layer and are perpendicular To the grain of the wood. The environmental ranges in RH had to have exceeded 70% to 20% for this damage to occur. The wood is acting as a restraint to the gesso layer.

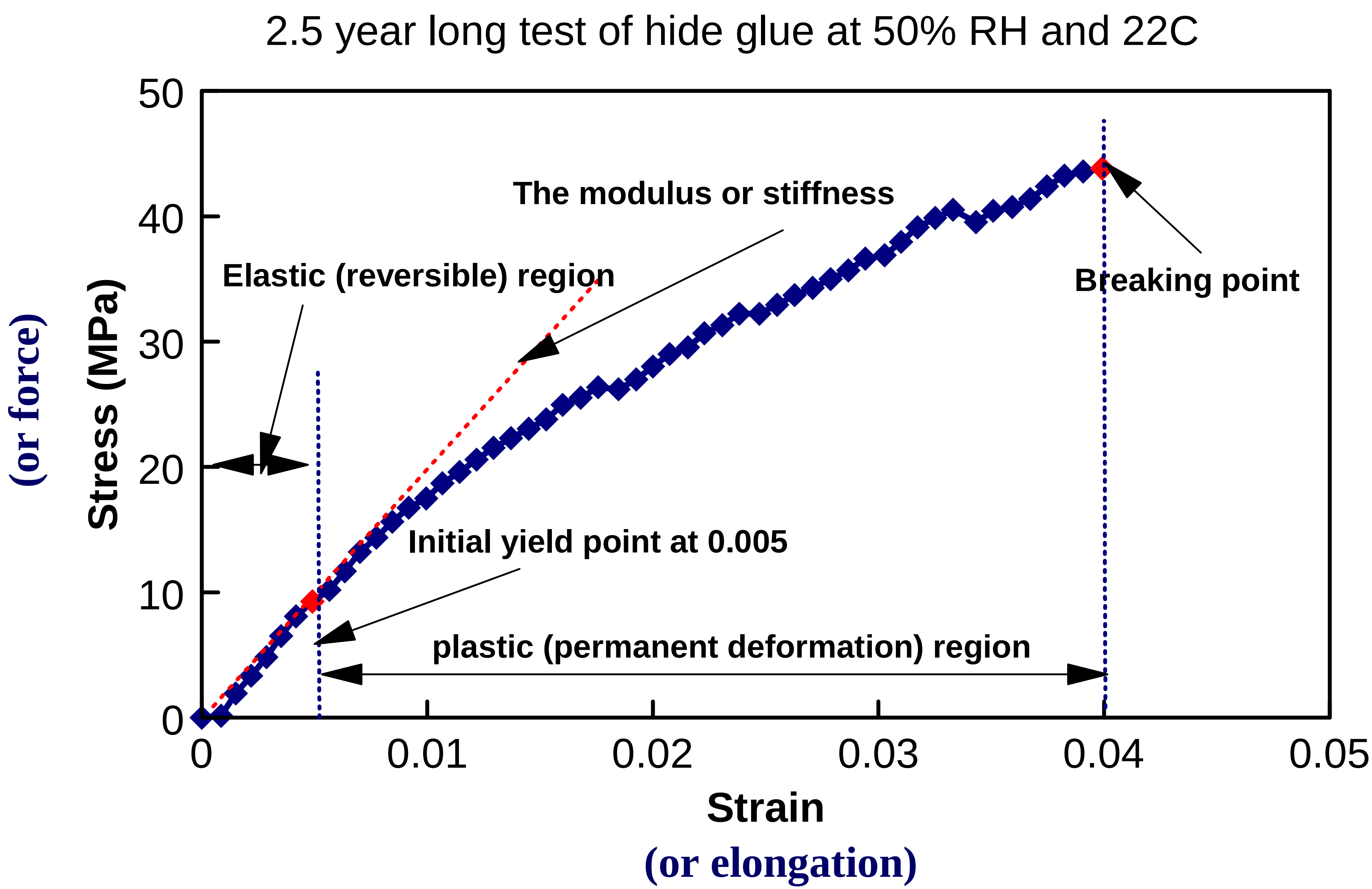
We keep referring to the adverse effects of fluctuating RH. What is the difference between the set point and allowable fluctuations?

RELATIVE HUMIDITY STABILITY ZONES

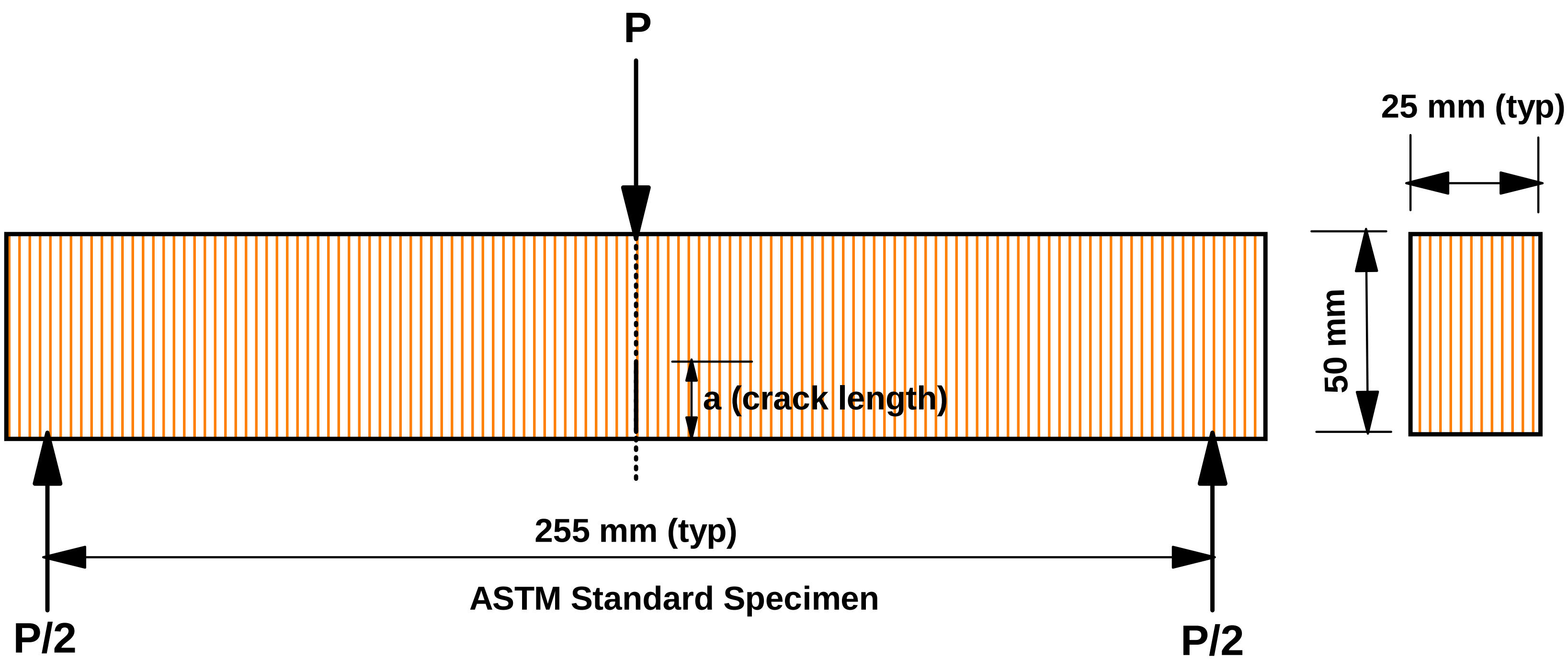


But as David Erhardt said we used the yield point of materials to determine The allowable fluctuation.

The stress strain test: Stress is force divided by the cross-sectional area of the sample and Strain is the change in the sample length divided by it original length.

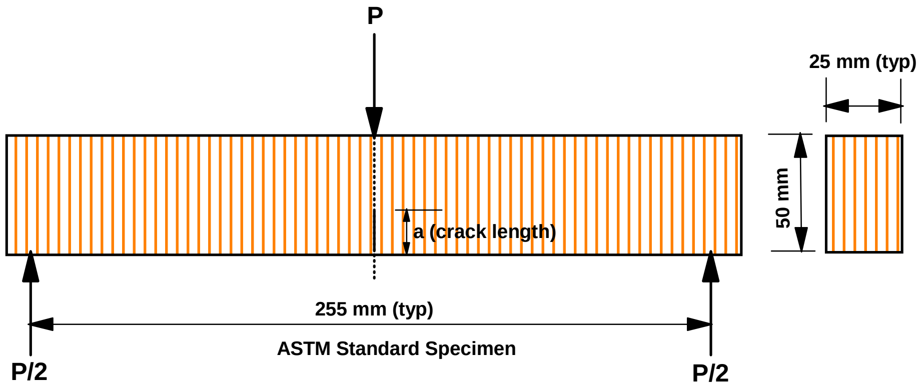


It has been suggested in some talks that any RH fluctuation causes damage, this is not necessarily true.

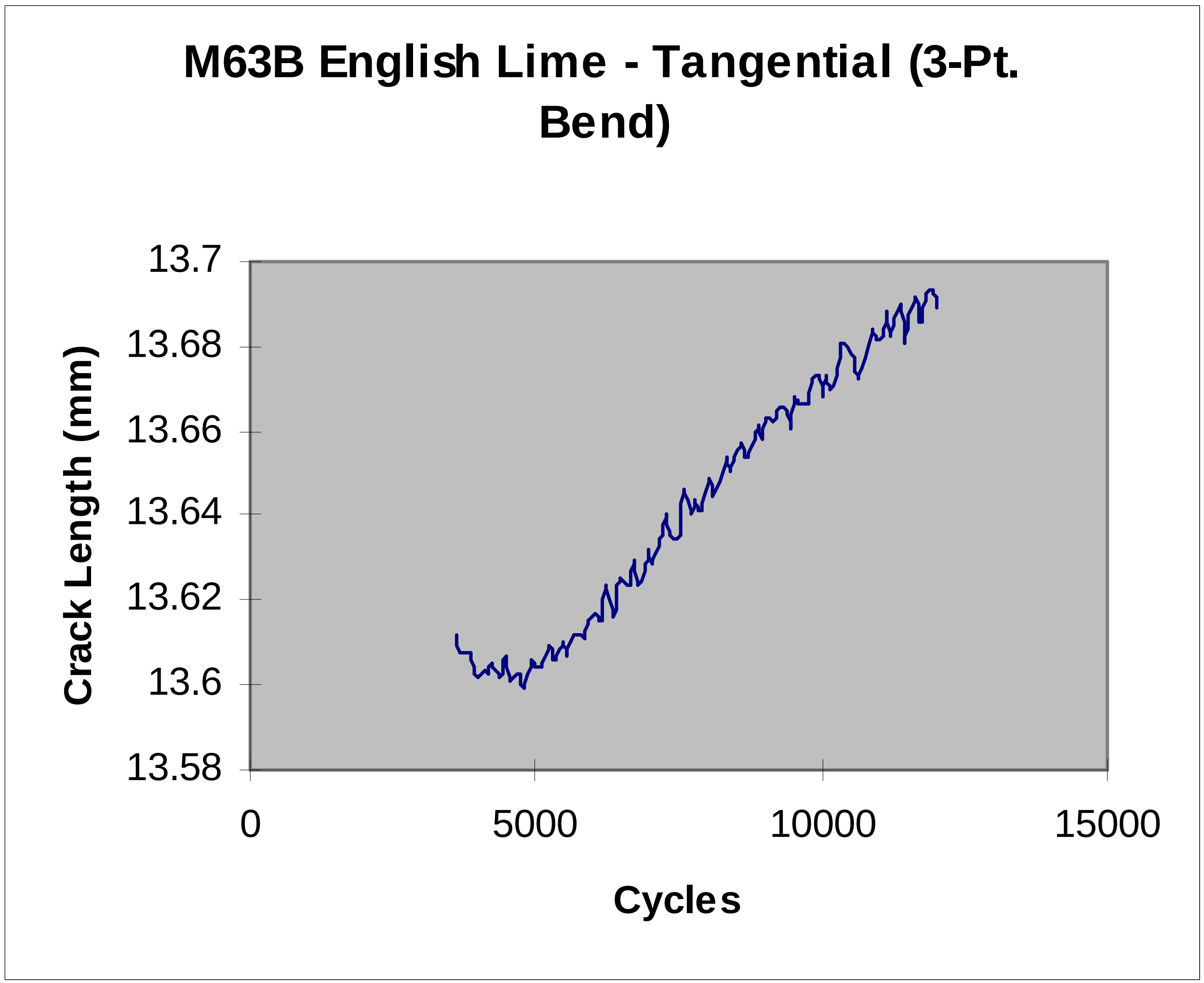


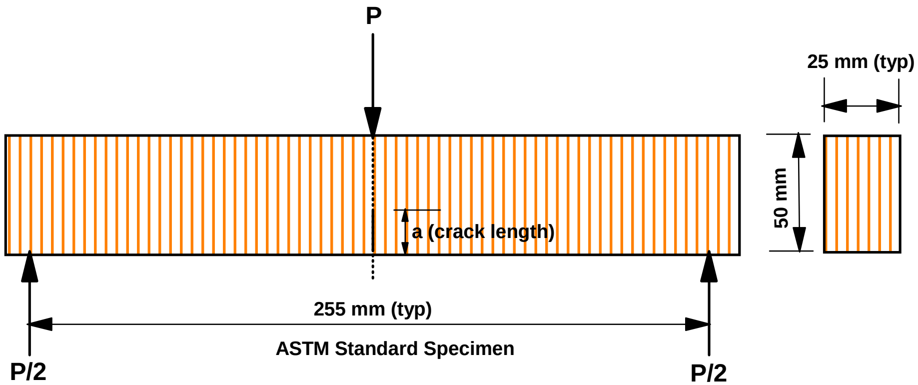
Cyclic Fatigue Results of English Lime Wood.
Cycle from P_1 to P_2 at 3 Hertz

Crack tip length calculated by Crack Tip Opening Displacement (CTOD) and periodically checked using a microscope.

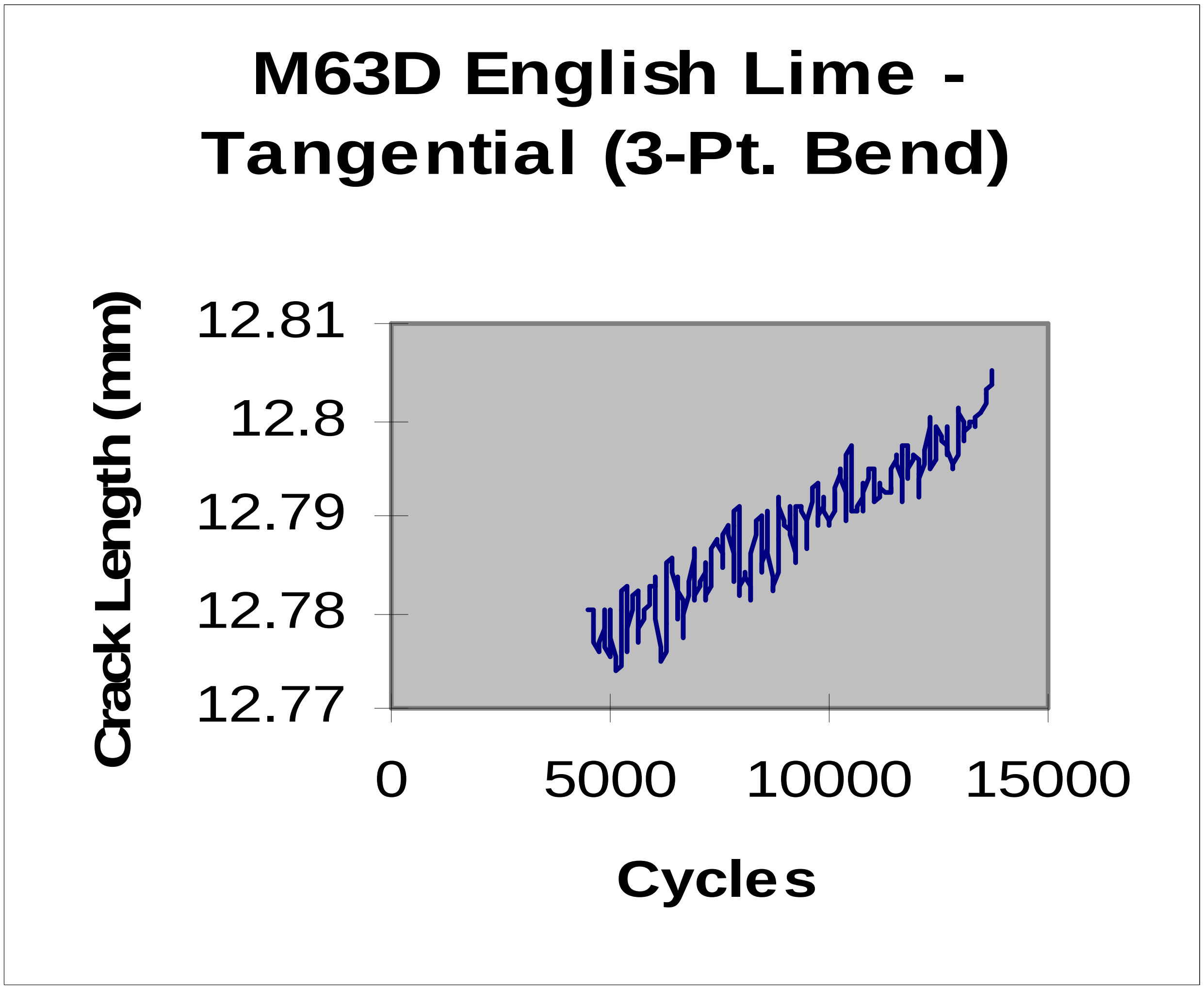


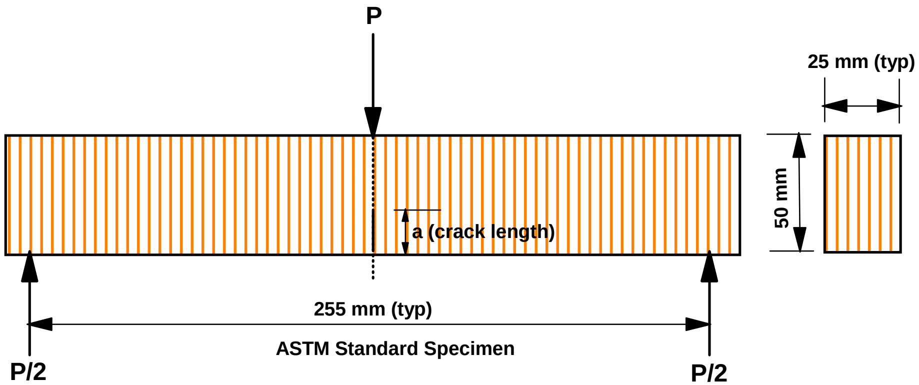
Load range
35 N to 343 N @ 3 hertz.
Change in crack length ~0.10mm



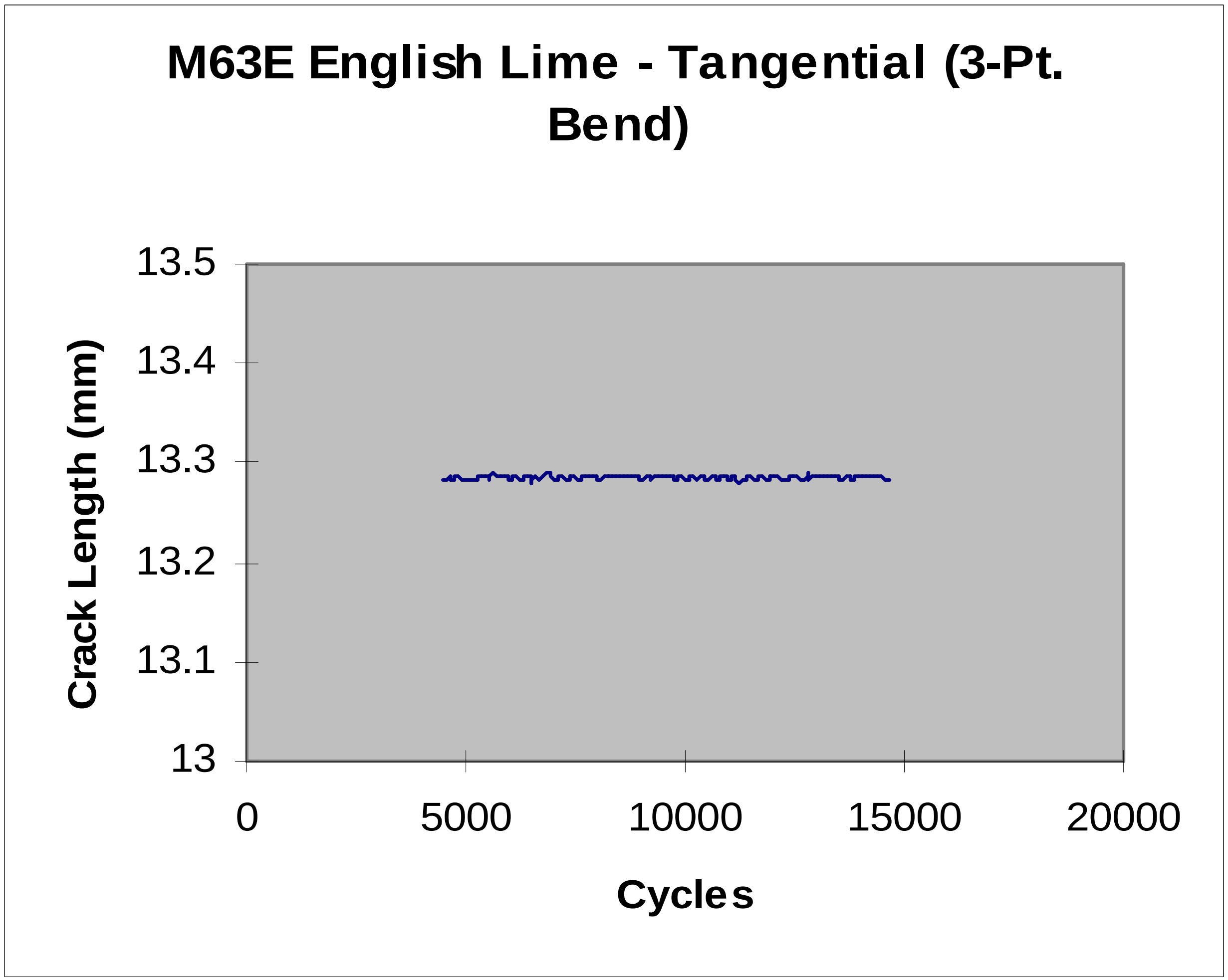


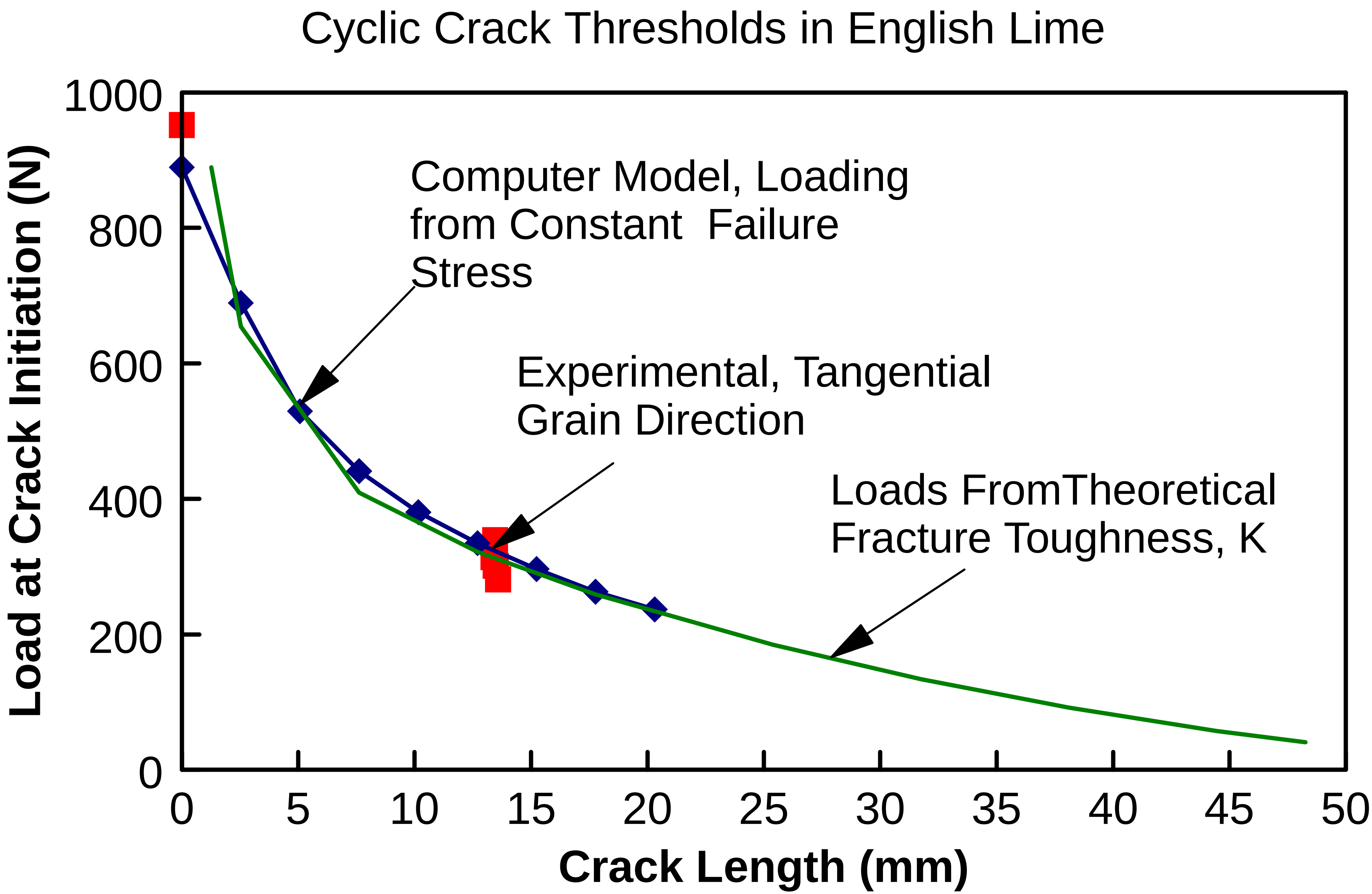
Load range
31.6 N to 302 N @ 3 hertz.
Change in crack length ~0.03 mm



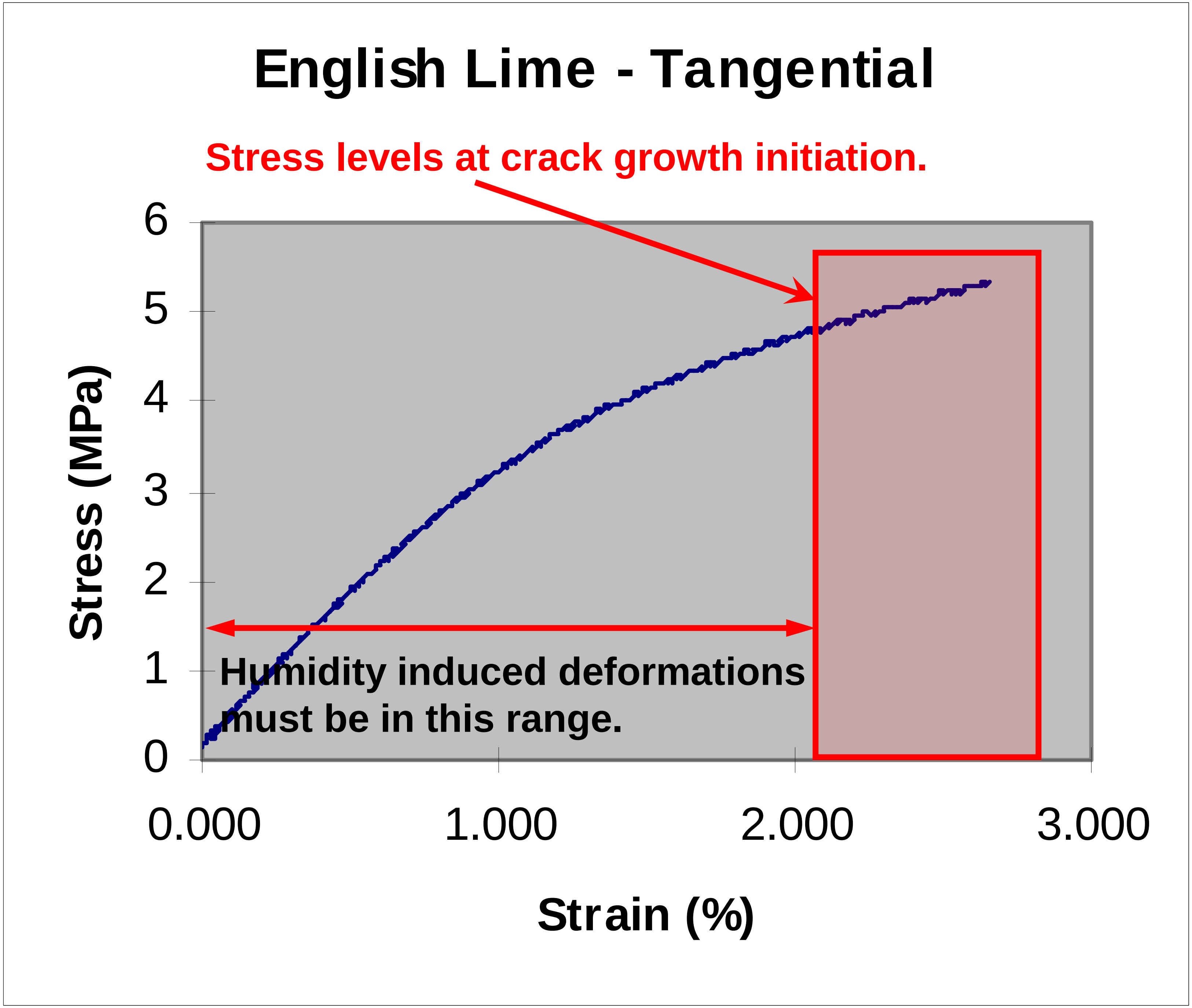


Load range
29 N to 285 N @ 3 hertz.
No change in crack length

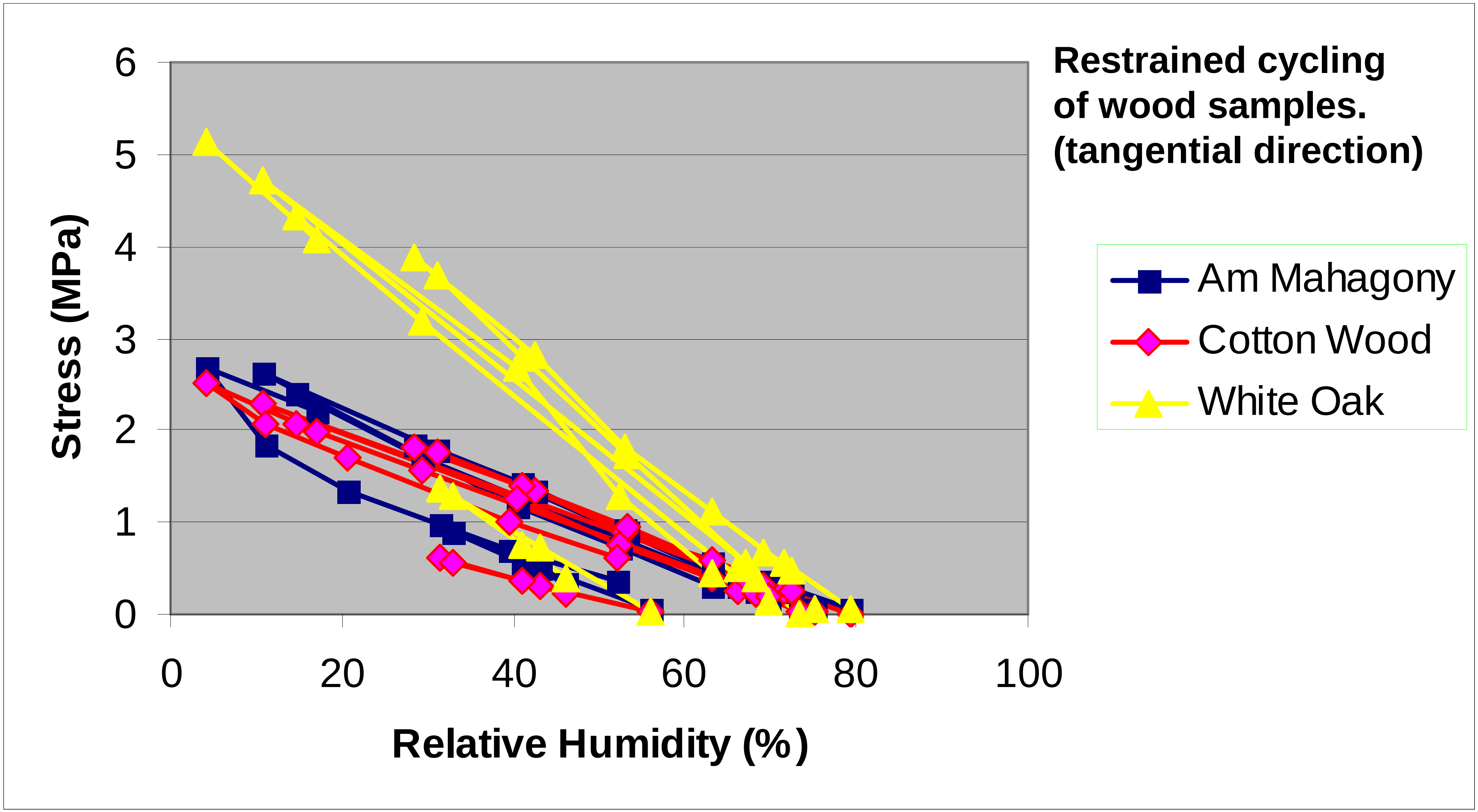




There is a threshold for fatigue below which cracks do not continue to grow.


English Lime - Tangential
Stress levels at crack growth initiation.
Stress (MPa)
0
1
2
3
4
5
6
Humidity induced deformations must be in this range.
0.000
1.000
2.000
3.000
Strain (%)

Woods can sustain considerable cyclic fatigue as well as large changes in RH when restrained.



Where do we go next?

There are a lot of questions that could be answered by including mechanics into the discussions. If we can establish safe RH and RH ranges for objects we can:

- Target case designs and know when they are really needed.
- Know what heating systems will work best for churches.
- Develop an accurate assessment of the effectiveness of both active and passive environmental controls.
- Incorporate energy costs into the equation.

We have a large data base of information on the mechanical and dimensional properties of cultural materials and have developed modeling protocols to assist researchers who might be interested.

Contact information:

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