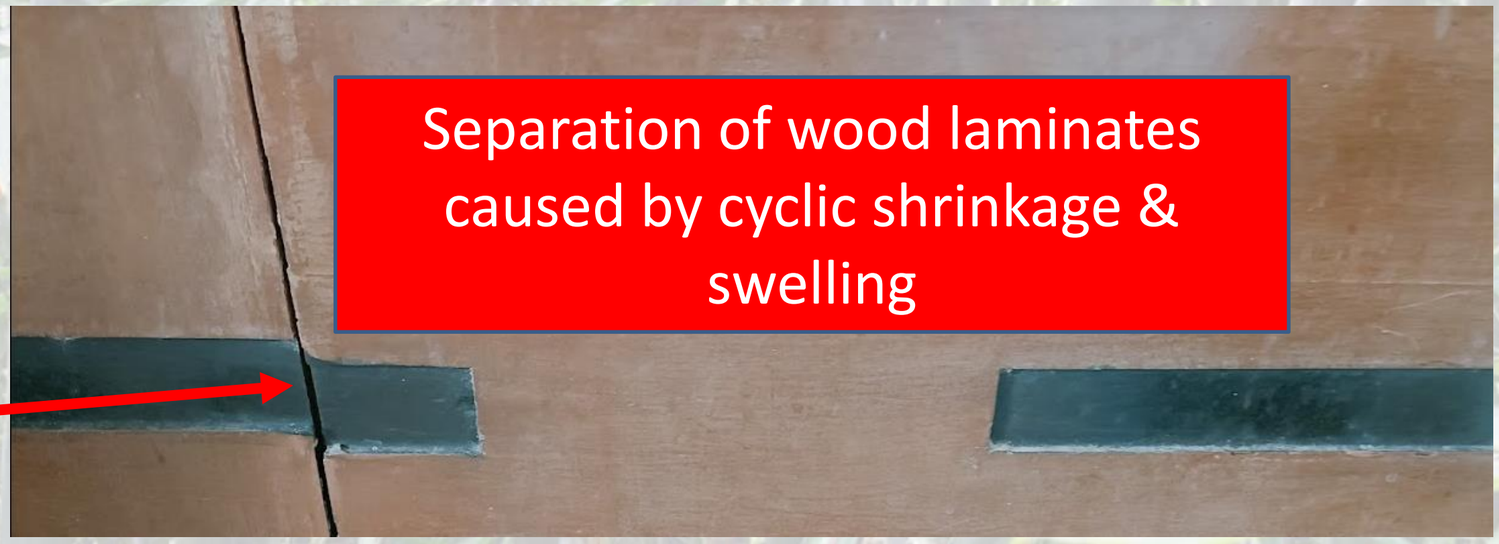

Separation of wood laminates caused by cyclic shrinkage & swelling

Delamination of laminates (wood or bamboo) caused by cyclic changes in humidity of an air-conditioned room or outside atmospheric conditions necessitates appropriate glue

Separation of bamboo laminates caused by cyclic shrinkage & swelling

INTRODUCTION / BACKGROUND OF THE STUDY

Office of the President of the Philippines. . Executive Order No. 879, s. 2010.

- creating the Philippine Bamboo Industry Development Council (PBDIC) to promote the bamboo industry development project and directing the use of bamboo for at least twenty-five (25%) percent of the desk and other furniture requirements of public elementary and secondary schools and prioritizing the use of bamboo in furniture, fixtures and other construction requirements of government facilities and allocating funds therefore and other purposes

SECTION 5. Department of Science and Technology. – The Department of Science and Technology (DOST), through its appropriate bureaus and offices like the Forest Products Research and Development Institute (FPRDI) and Food and Nutrition Research Institute (FNRI), shall undertake the research and transfer of technologies which can reduce production costs and increase the saleability of bamboo products such as bamboo shoots processing and packaging, alternative adhesives and finishes, and effective yet affordable treatment and preservation techniques. It shall likewise allocate twenty percent (20%) of its MSME assistance funds such as SET-UP and TAPI Venture Capital to bamboo based enterprises.

Project 2:
Development of Protective Processing Technology
for Bamboo Musical Instruments

Glue bond Performance of *Dendrocalamus asper* Using Cold setting and Thermosetting Adhesives

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&
James Edelbert C. Ramos, M.S.

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Forest Products Research and Development Institute

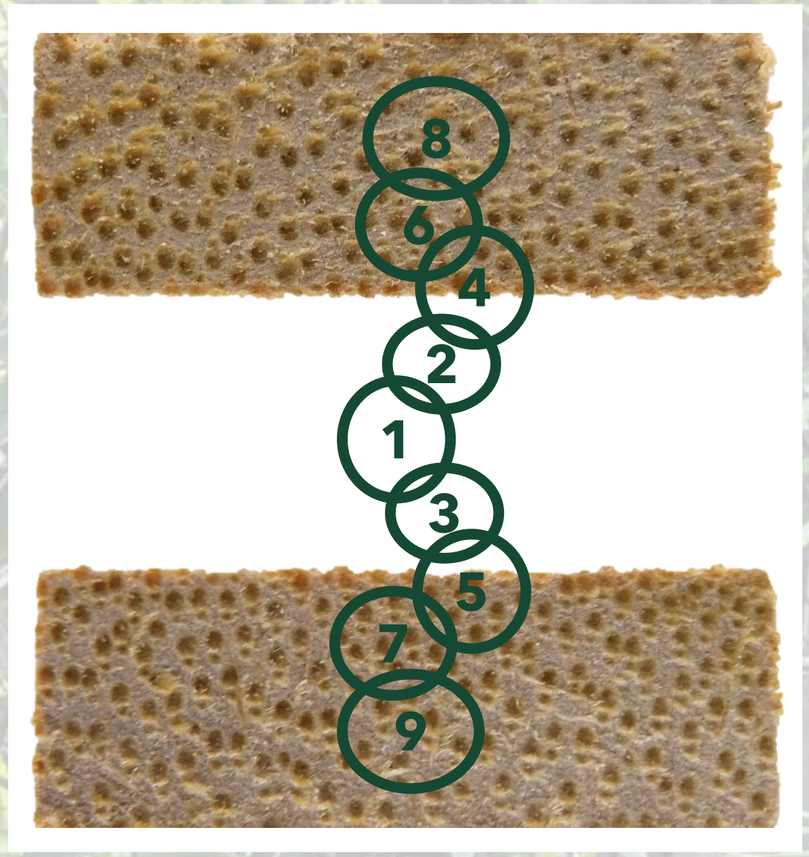
Department of Science and Technology
Philippine Council for Industry, Energy, and Emerging Technology Research and Development

INTRODUCTION / BACKGROUND OF THE STUDY

Bamboo Lamination

- Process of **gluing together** bamboo materials to form **engineered bamboo** and is used as base material for various applications
- As a laminated product, engineered bamboo is **comparable or even superior in mechanical strength to solid wood**.

Principle of Lamination



Chain Analogy of Adhesive Bonding

1	-	Bulk adhesive
2 & 3	-	Adhesive interphase
4 & 5	-	Bamboo-Adhesive Interface
6 & 7	-	Bamboo interphase
8 & 9	-	Bulk bamboo

OBJECTIVES OF THE STUDY

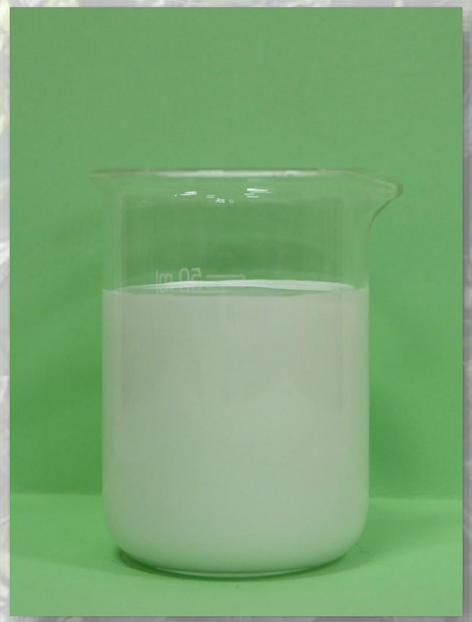
- compare the performance of cold setting (PVAc and PUR) and hot-setting (UF and PF) adhesives;
- determine the effect of the surface pairing of giant bamboo laminates;
- determine the effect of glue spread rate on the bond strength of the giant bamboo laminates.

MATERIALS & METHODS

Adhesives Used

- **Cold-Setting Adhesives**
  adhesives that set without the application of heat.

- **Hot-Setting Adhesives**
  adhesives that requires heat to set (polymerization).



Polyvinyl Acetate (D3)

Polyurethane

Urea Formaldehyde

Phenol Formaldehyde

MATERIALS & METHODS

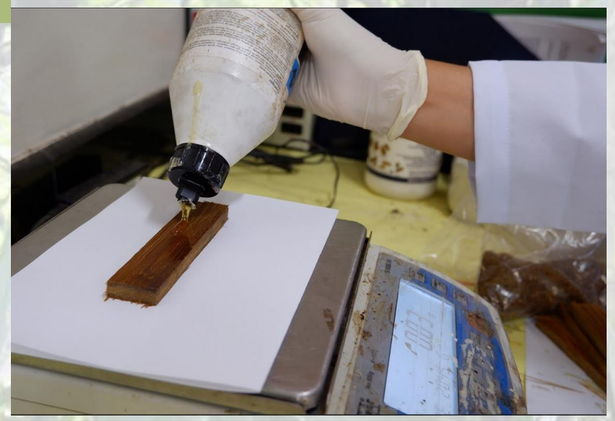
Lamination Process

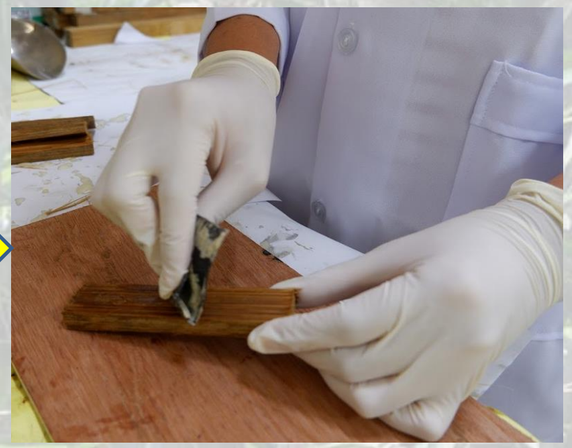
1. Ripsawing of poles to produce splits.
2. Planing of splits to produce slats.
3. Coating of slats with the preferred adhesive.
4. Pressing of laminated slats in a pneumatic press (cold-setting) or hot press (hot-setting).




MATERIALS & METHODS

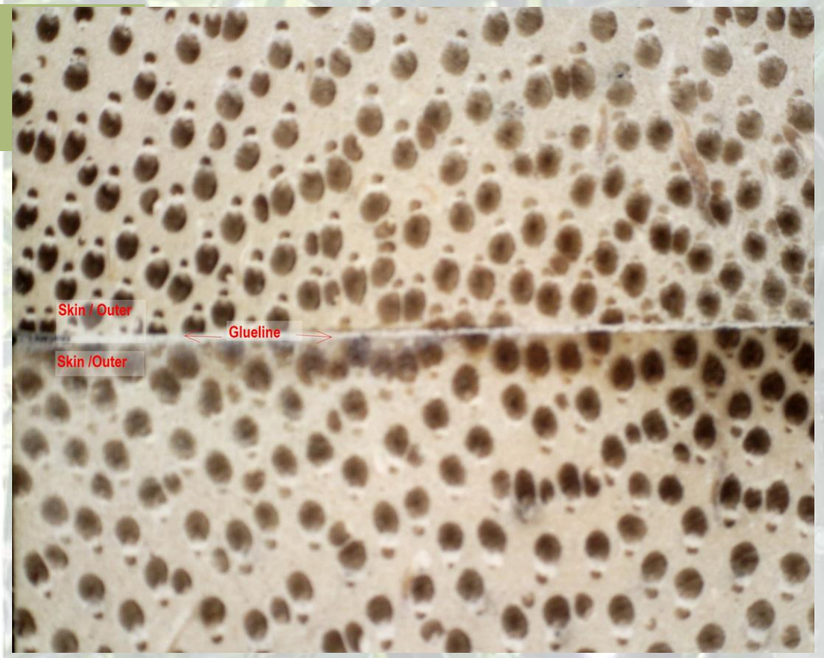
Lamination Process



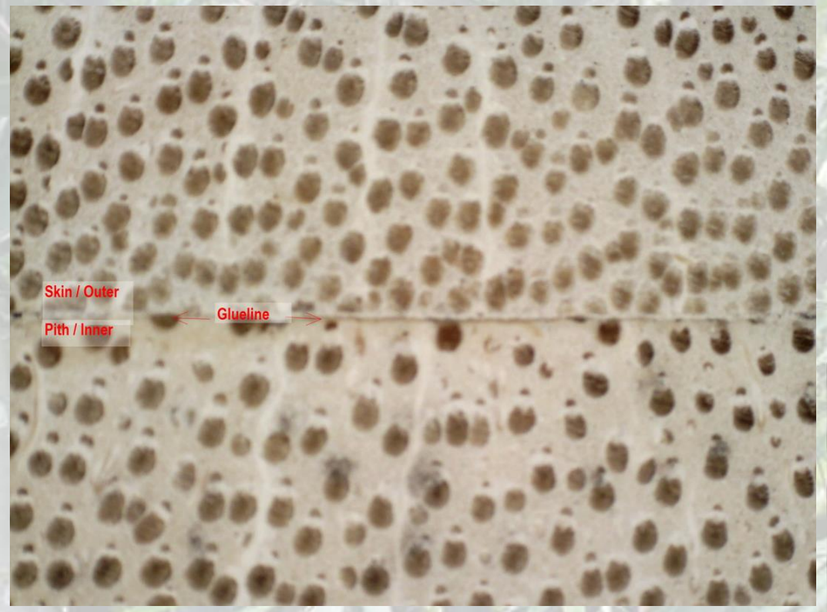


Surface Pairing	Glue Spread (g/m^2)
Inner-inner or Pith-Pith	100 150 200
Outer-Outer or Skin-Skin	100 150 200
Outer-Inner or Skin-Pith	100 150 200

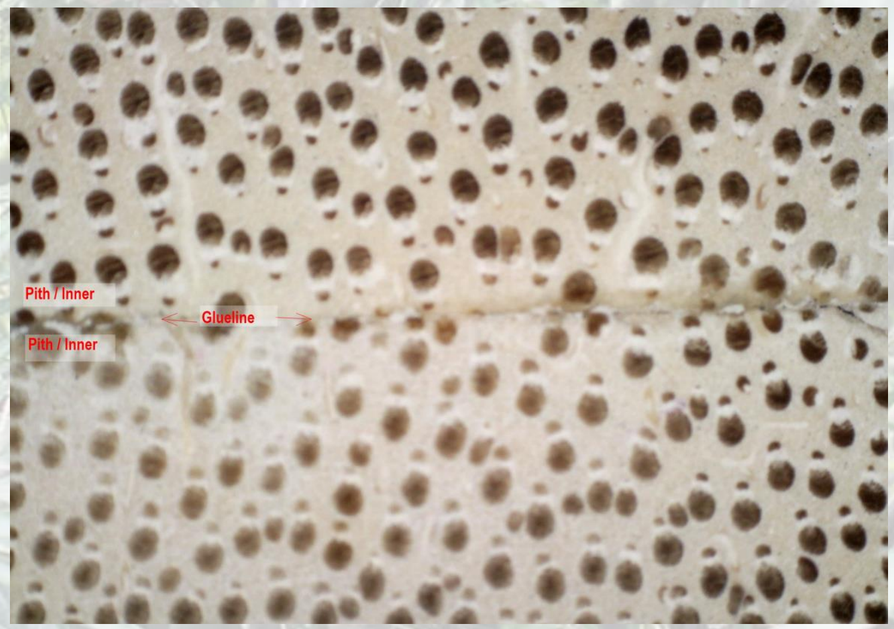
Bamboo Laminates Surface Pairing



Skin-Skin or Outer-Outer



Skin-Pith or Outer-Inner



Pith-Pith or Inner-Inner

Department of Science and Technology
Forest Products Research and Development Institute

Department of Science and Technology
Philippine Council for Industry, Energy, and Emerging Technology Research and Development

MATERIALS & METHODS

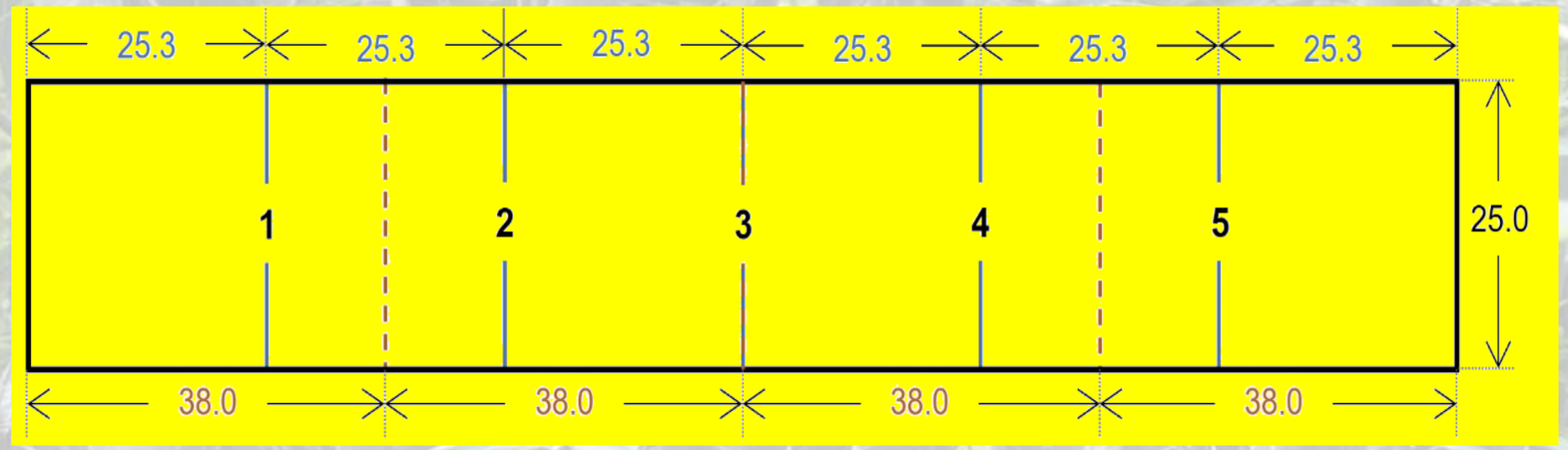
Response parameters measured

1. Surface roughness of laminates – outer/skin; inner/pith
2. Wettability of the laminates using the cold- and hot-setting adhesives
3. Dry and Wet Shear Strengths of the glued laminates
4. Dry and Wet Shear Bamboo Failure of the glued laminates – evaluated using the PNS 2099:2015 (Engineered Bamboo for general purpose - specification)

MATERIALS & METHODS

Response parameters measured

Surface roughness of laminates – outer/skin; inner/pith

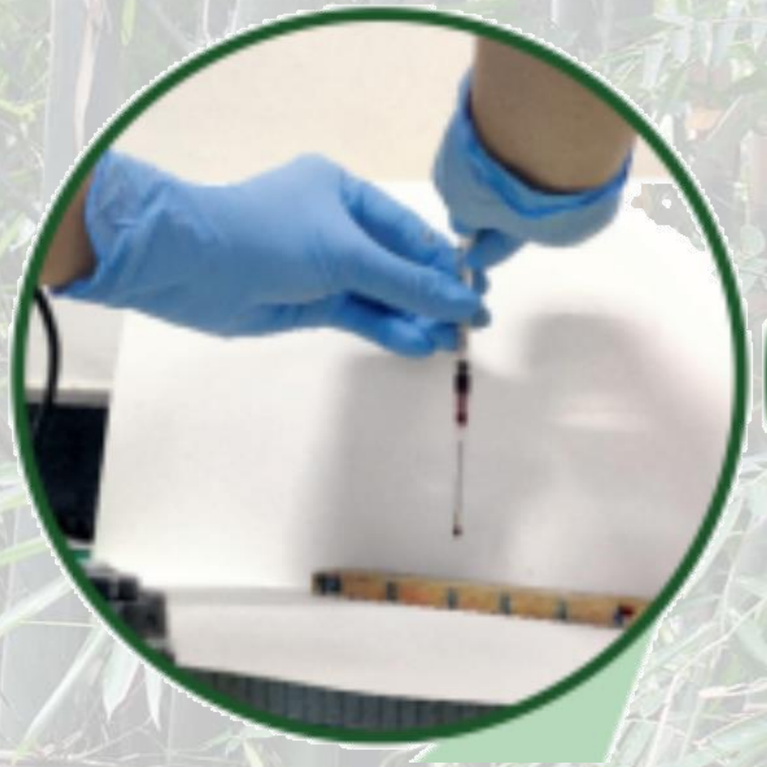


1

MATERIALS & METHODS

Response parameters measured

Wettability of the laminates using the cold- and hot-setting adhesives



2

MATERIALS & METHODS

Response parameters measured

Dry and Wet Shear Strengths of the glued laminates

3

MATERIALS & METHODS

Response parameters measured

Dry and Wet Shear Bamboo Failure of the glued laminates – evaluated using the PNS 2099:2015 (Engineered Bamboo for general purpose - specification)

4

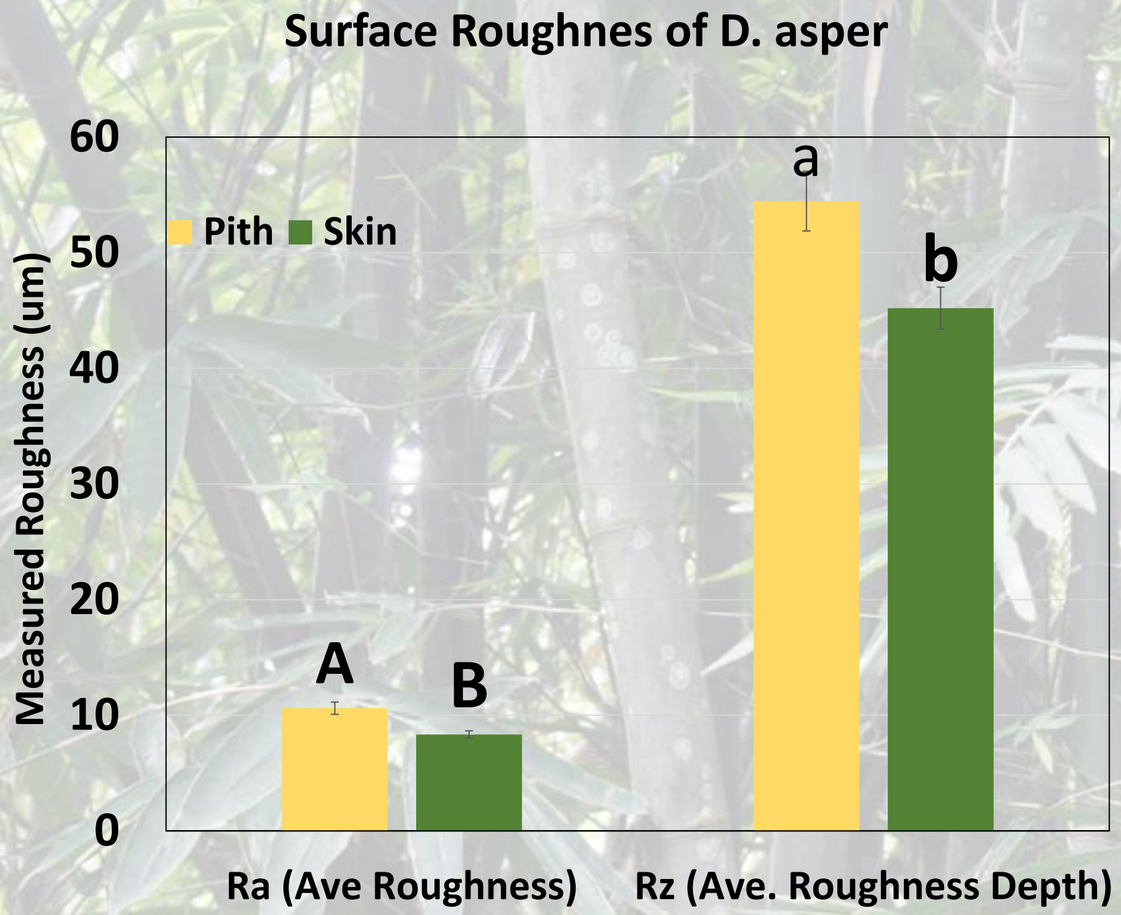
MATERIALS & METHODS

Statistical Analysis

- Experimental design for the surface roughness and wettability was a simple CRD and mean comparison was made using an unpaired t-test.
- A factorial experiment for the bond strength test was employed with adhesive, surface pairing, and glue spread rate as the main factors.
- Analysis of Variance (ANOVA) at a 5% significance level was performed to determine the difference of all parameters.
- Significant differences between the mean values were separated using Tukey's HSD. All statistical analysis was calculated using SAS 9.4 for Windows.

RESULTS

Research Findings

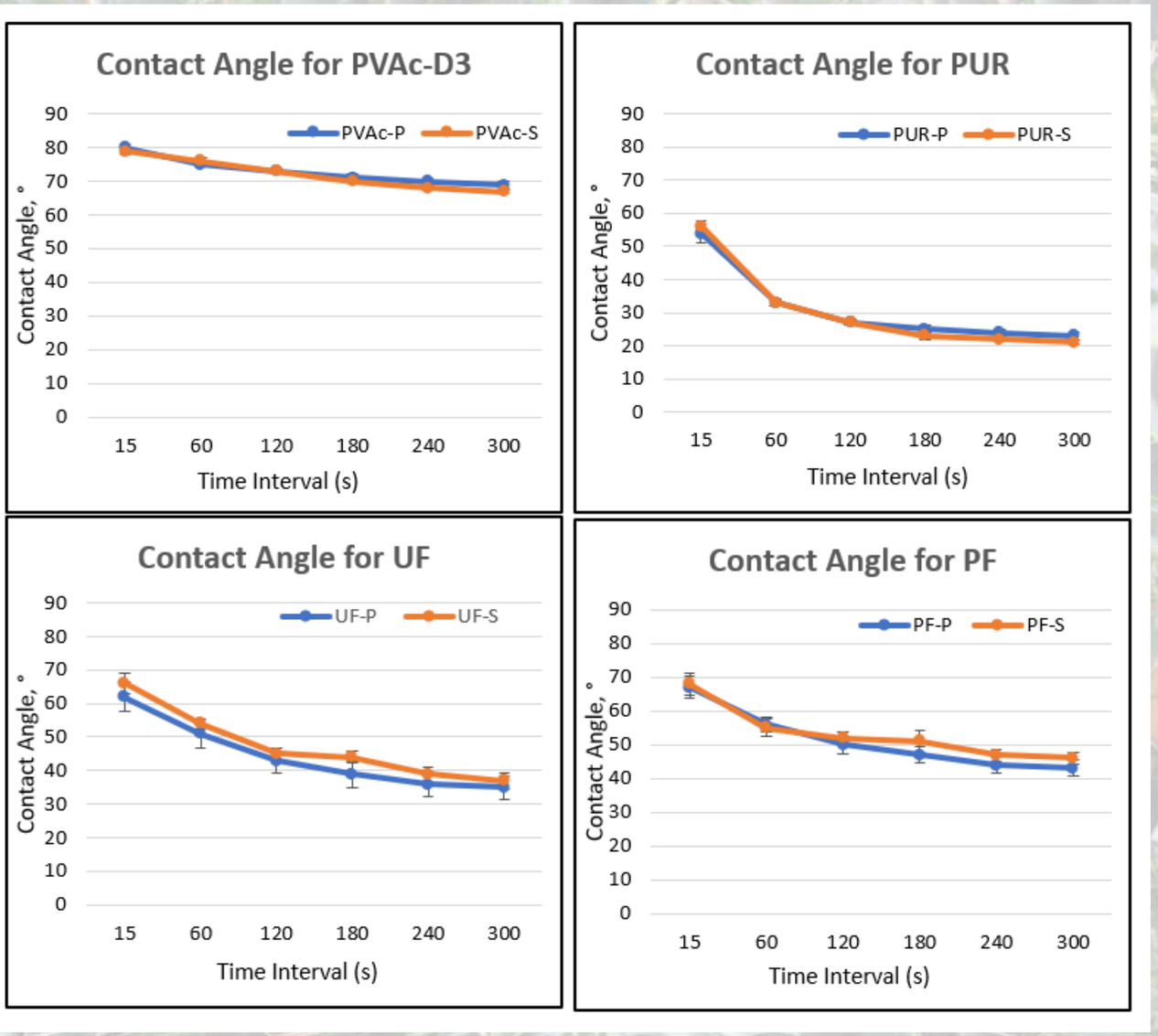


- The pith side of the slat is rougher than the skin side

RESULTS

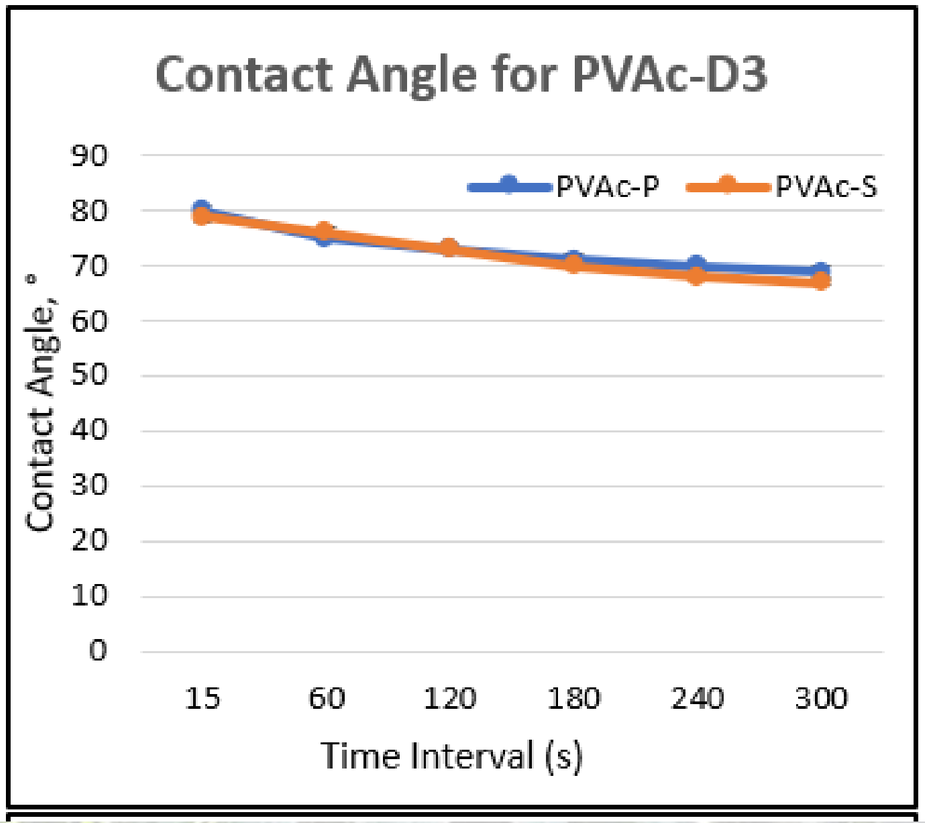
Wettability

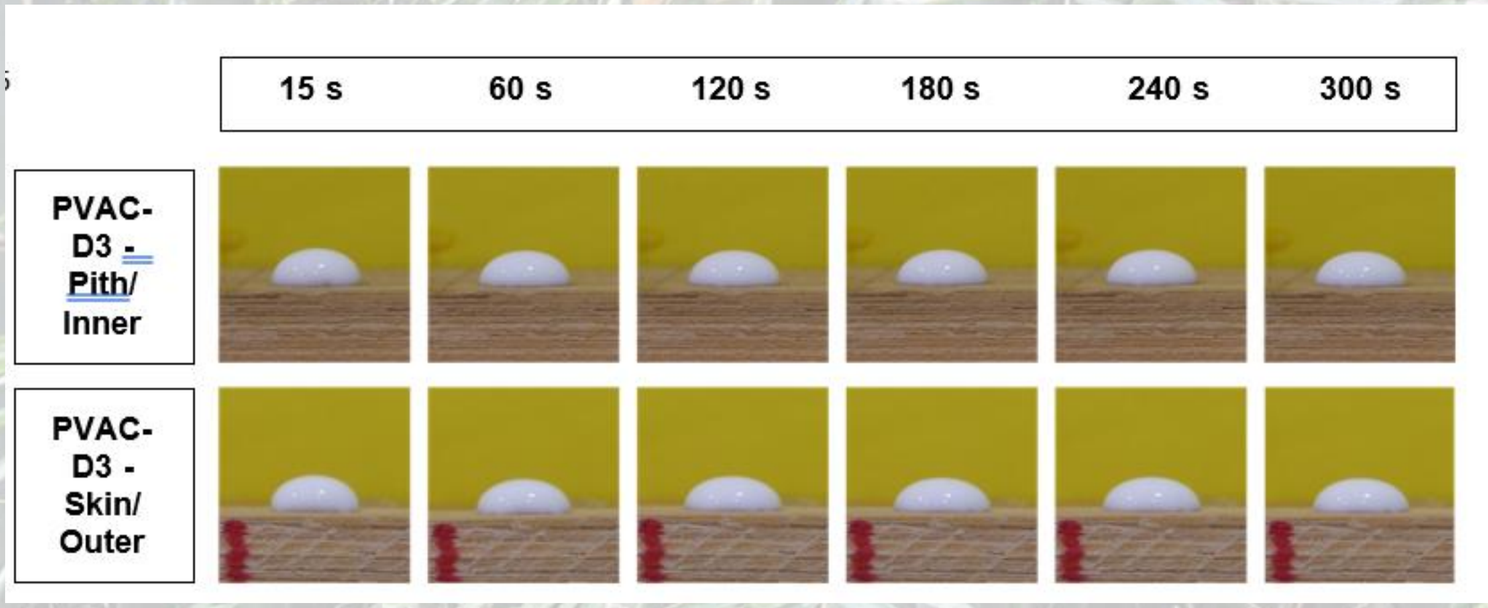
- For all 4 adhesives, the contact angle was highest with PVAc and lowest with PUR
- For the Hot-Setting glues UF has lower contact angle than PF
- For all 4 adhesives, the measured difference between the contact angle of pith and skin was not significantly different



RESULTS

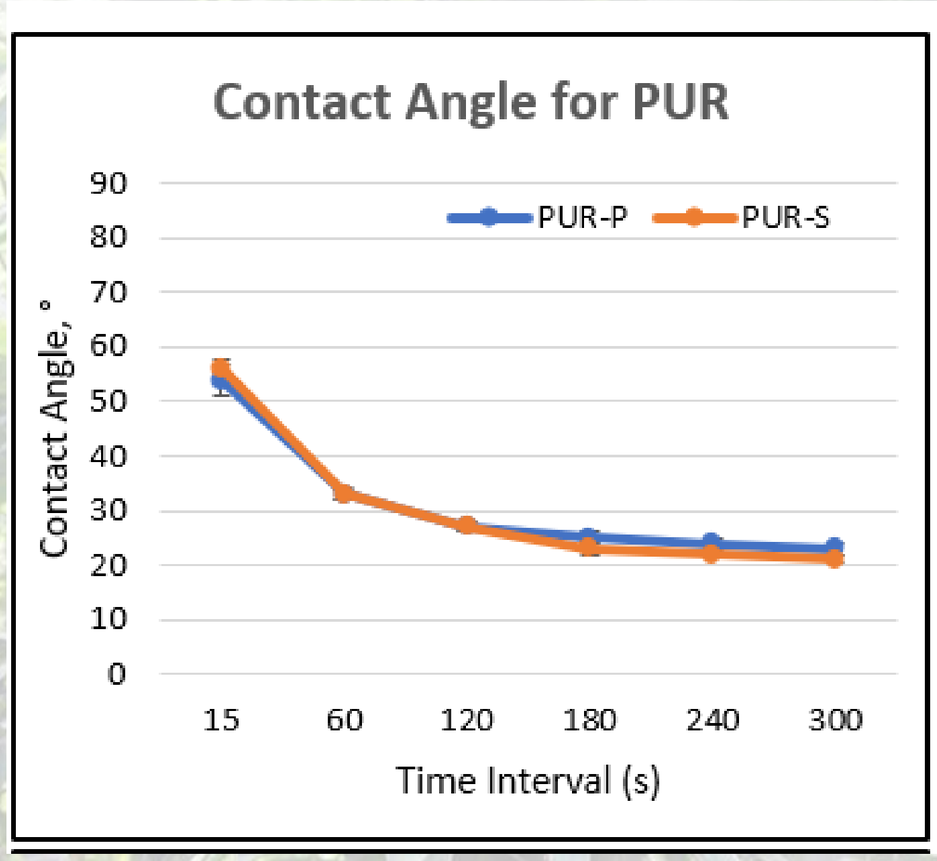
Wettability

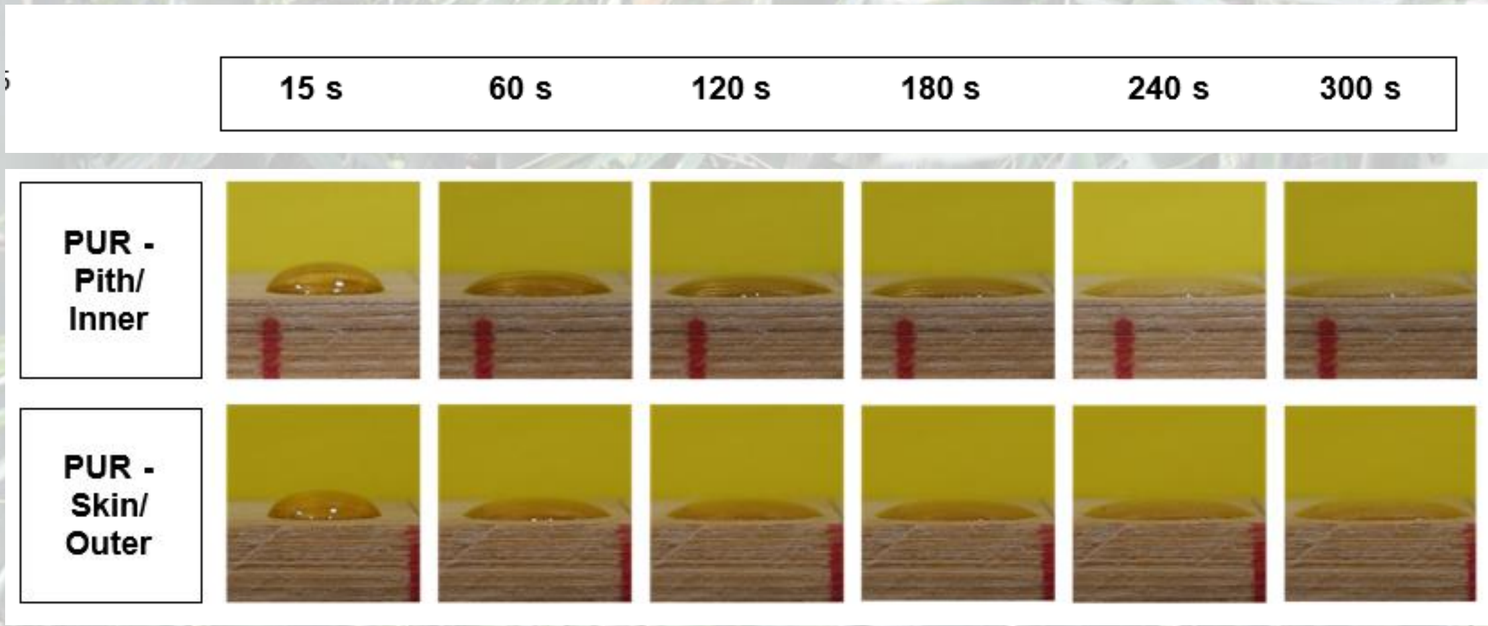




RESULTS

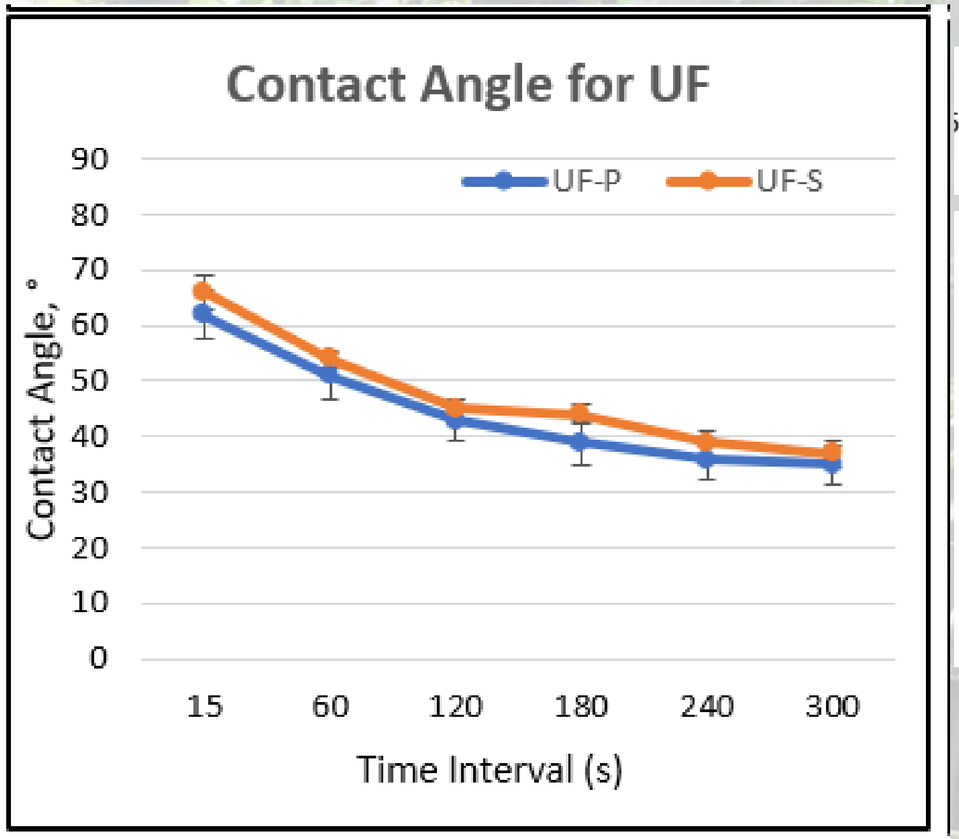
Wettability

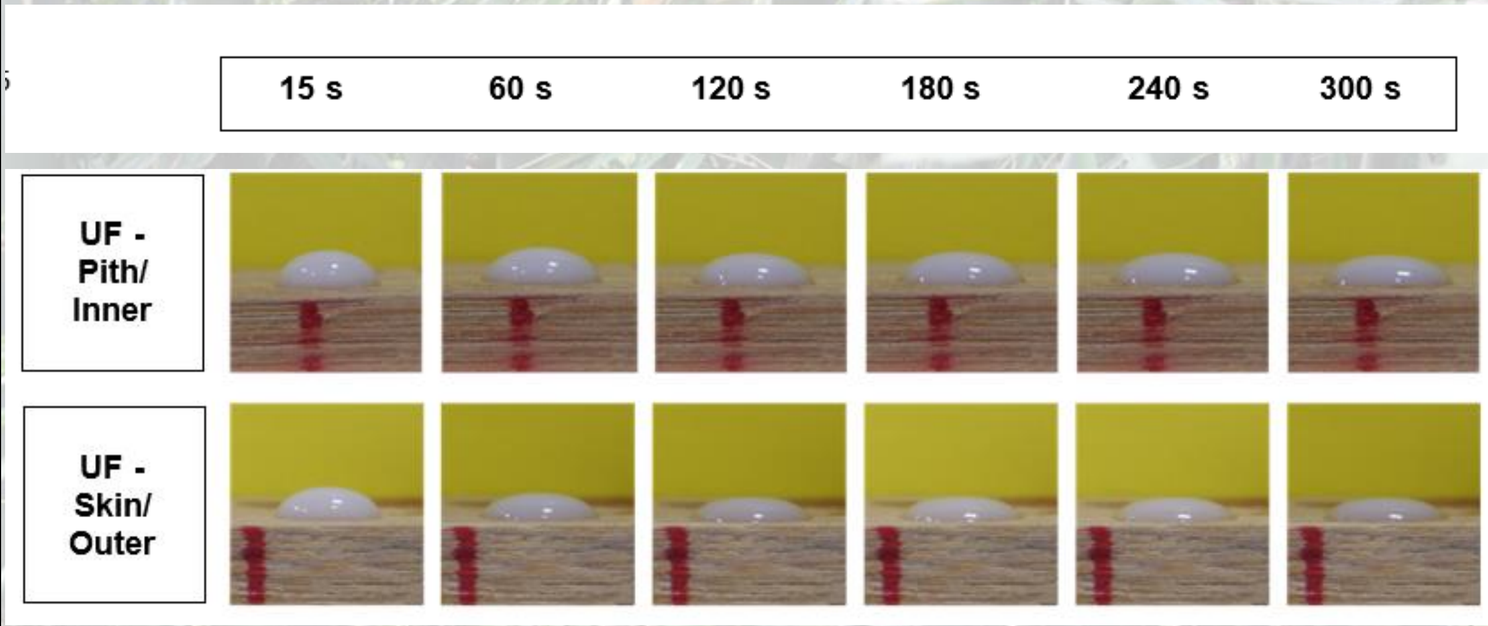




RESULTS

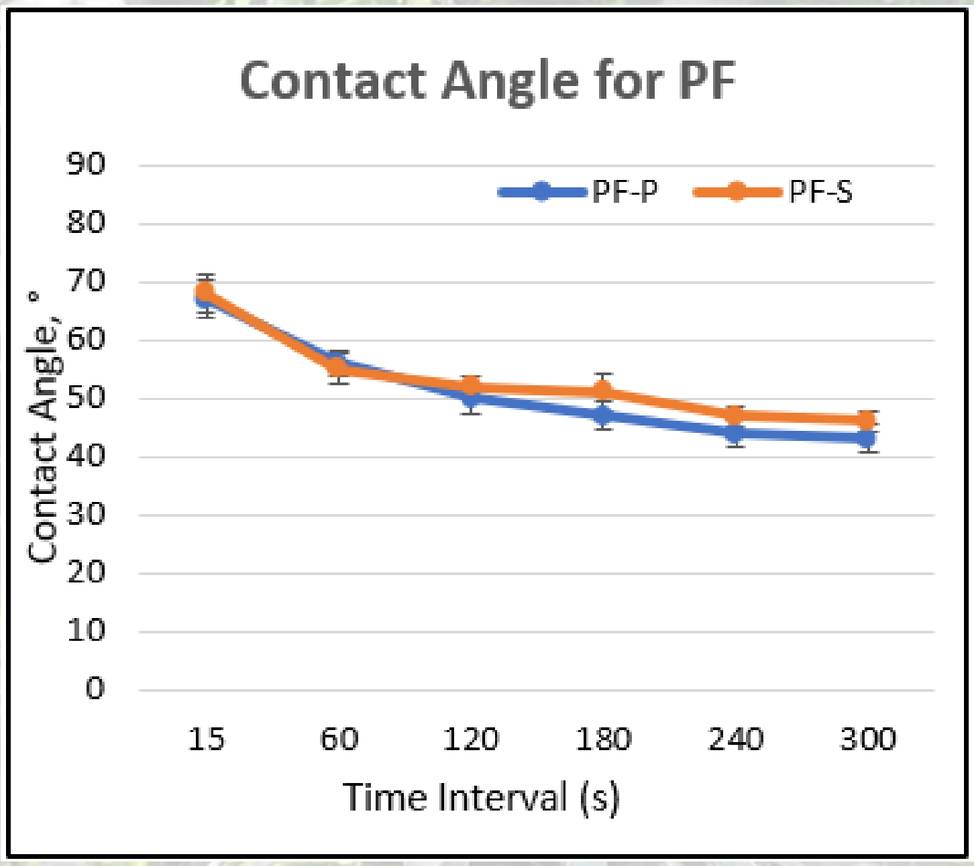
Wettability

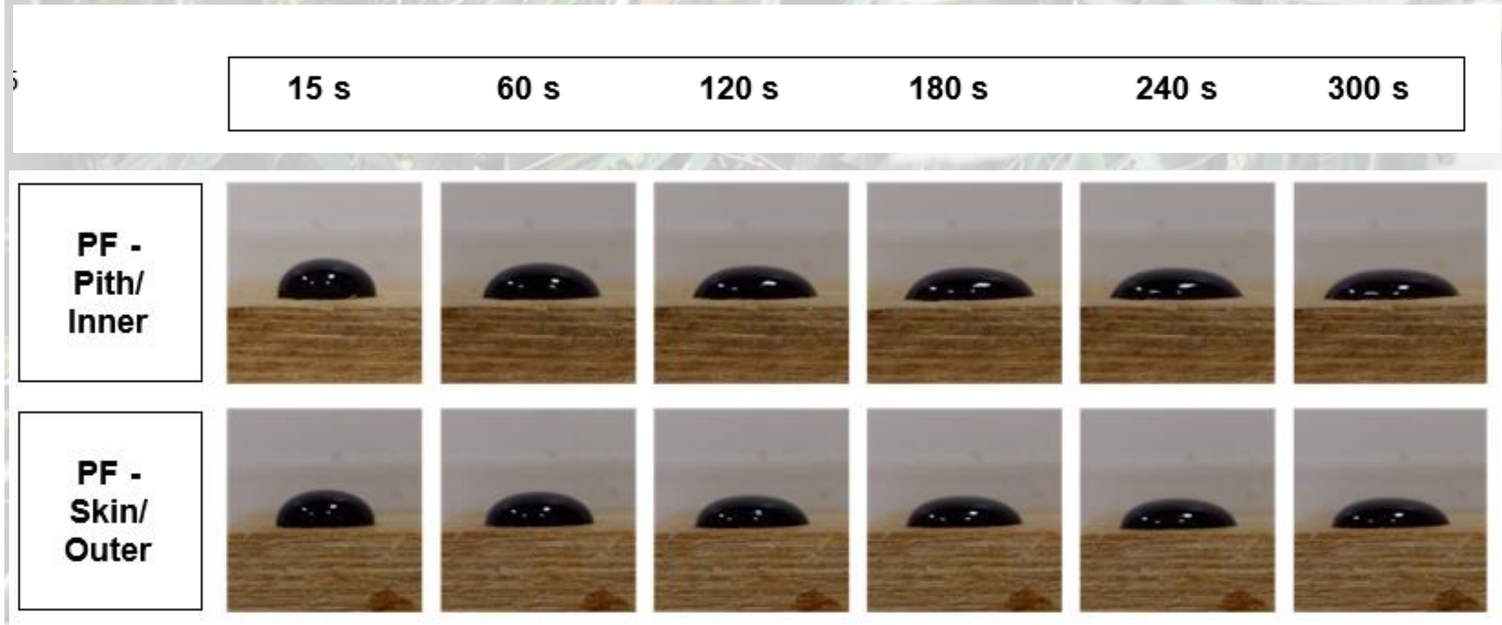




RESULTS

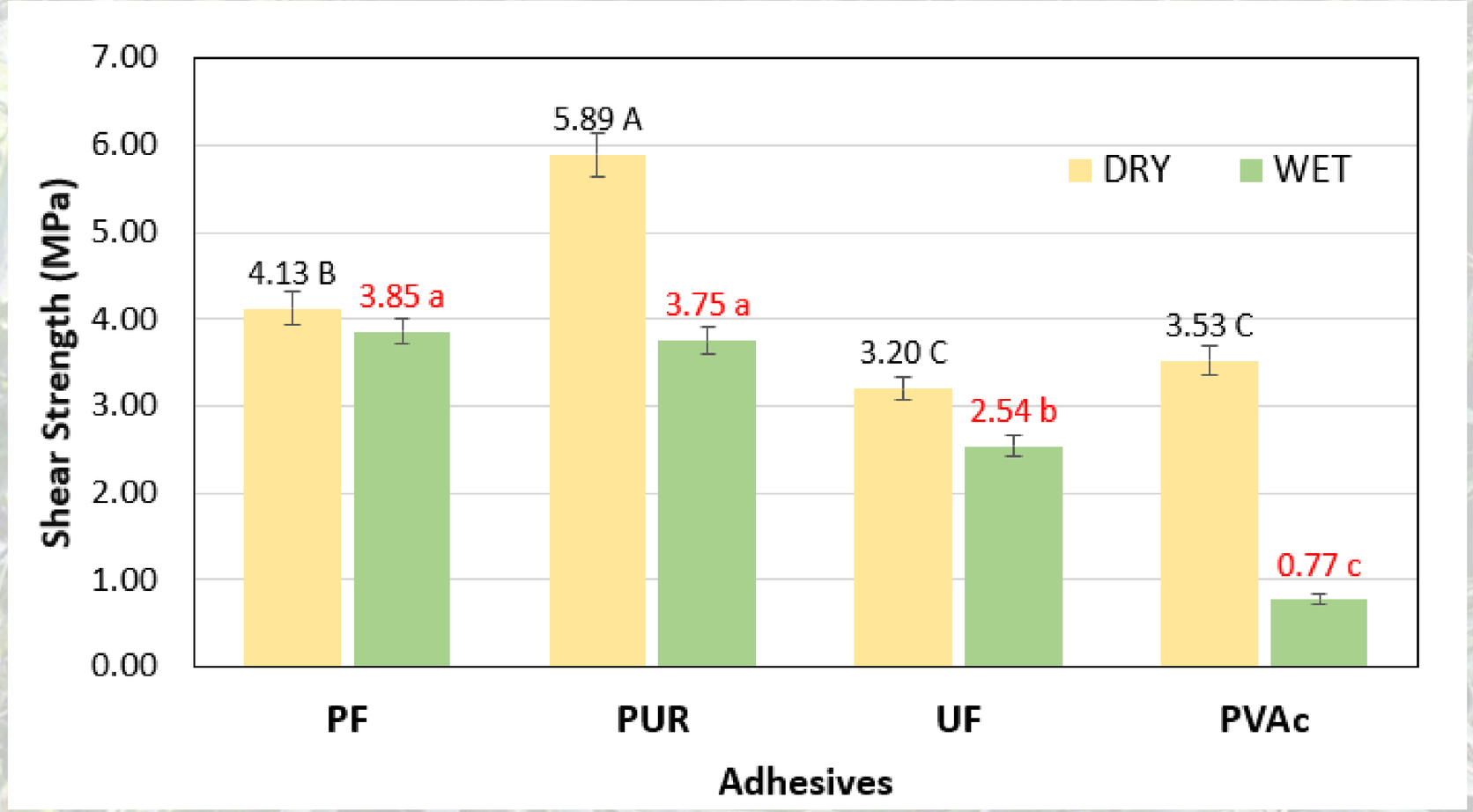
Wettability





RESULTS

Dry and Wet Shear Strength

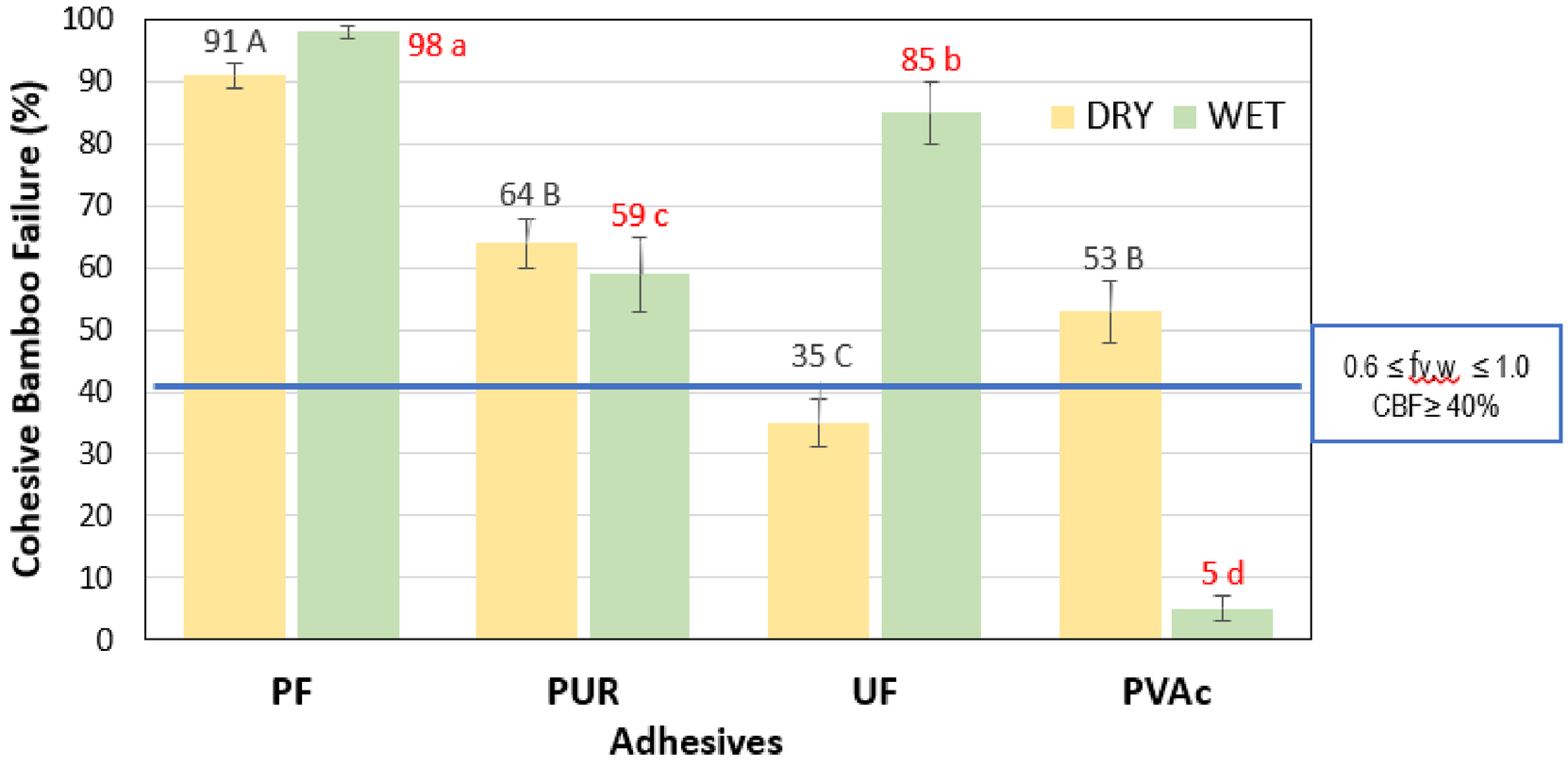


DSS:
PUR>PF>UF=PVAc

WSS:
PUR=PF>UF>PVAc

RESULTS

Dry and Wet Bamboo Failure



DBF:
PF>PUR=PVAc>UF

WSS:
PF>UF>PUR>PVAc

Note that PVAC failed the test or the bond requirements of the standard for BF in Wet Shear Test

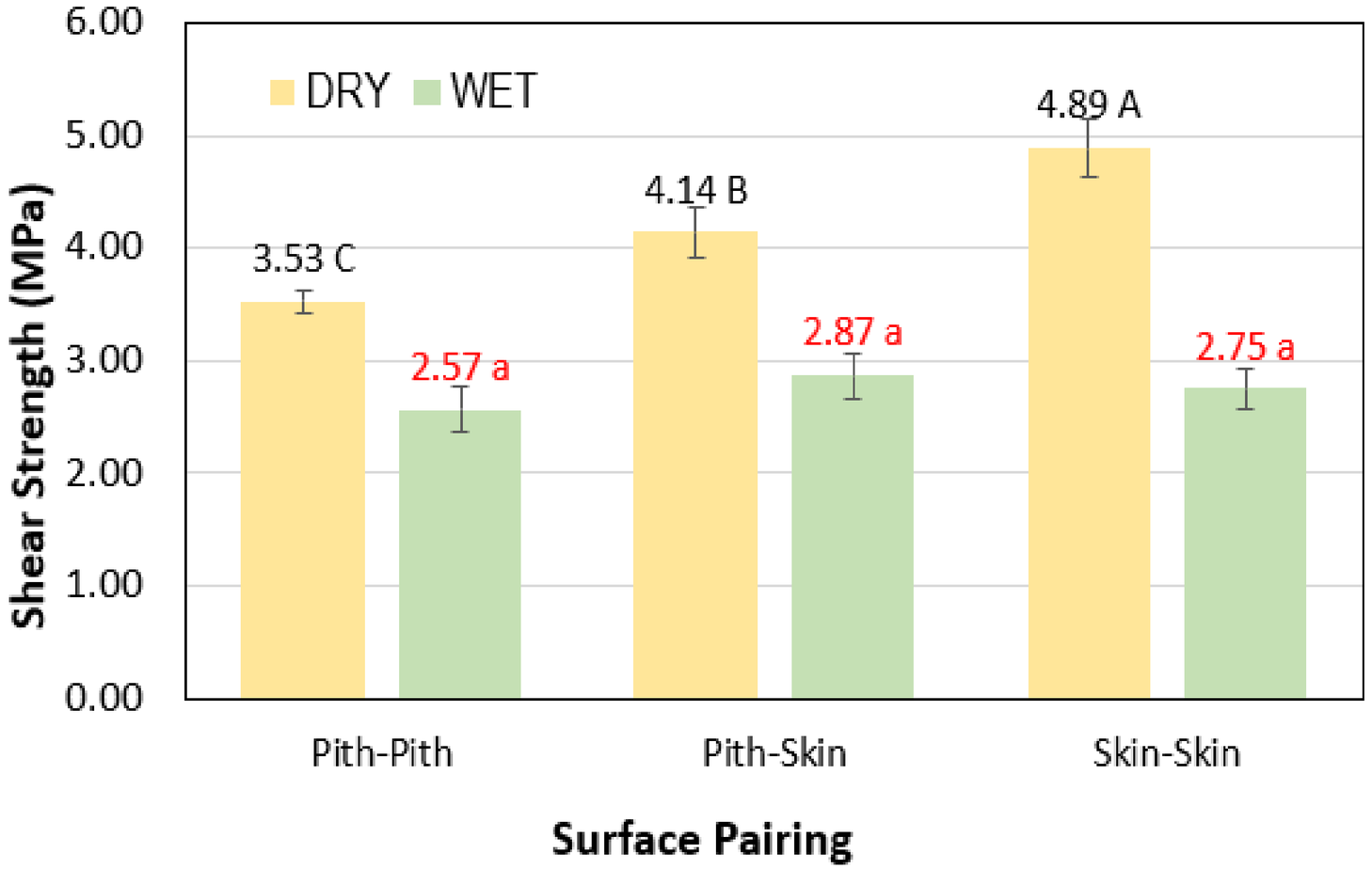
Significance of the glue/adhesive bond wet shear test

After heavy rains or post-typhoon scenes: Many of the Philippines' public classrooms' school furniture were usually submerged in floodwater

What will happen to an engineered laminated bamboo school furniture bonded by PVAC-D3 adhesive?

RESULTS

Surface Pairing

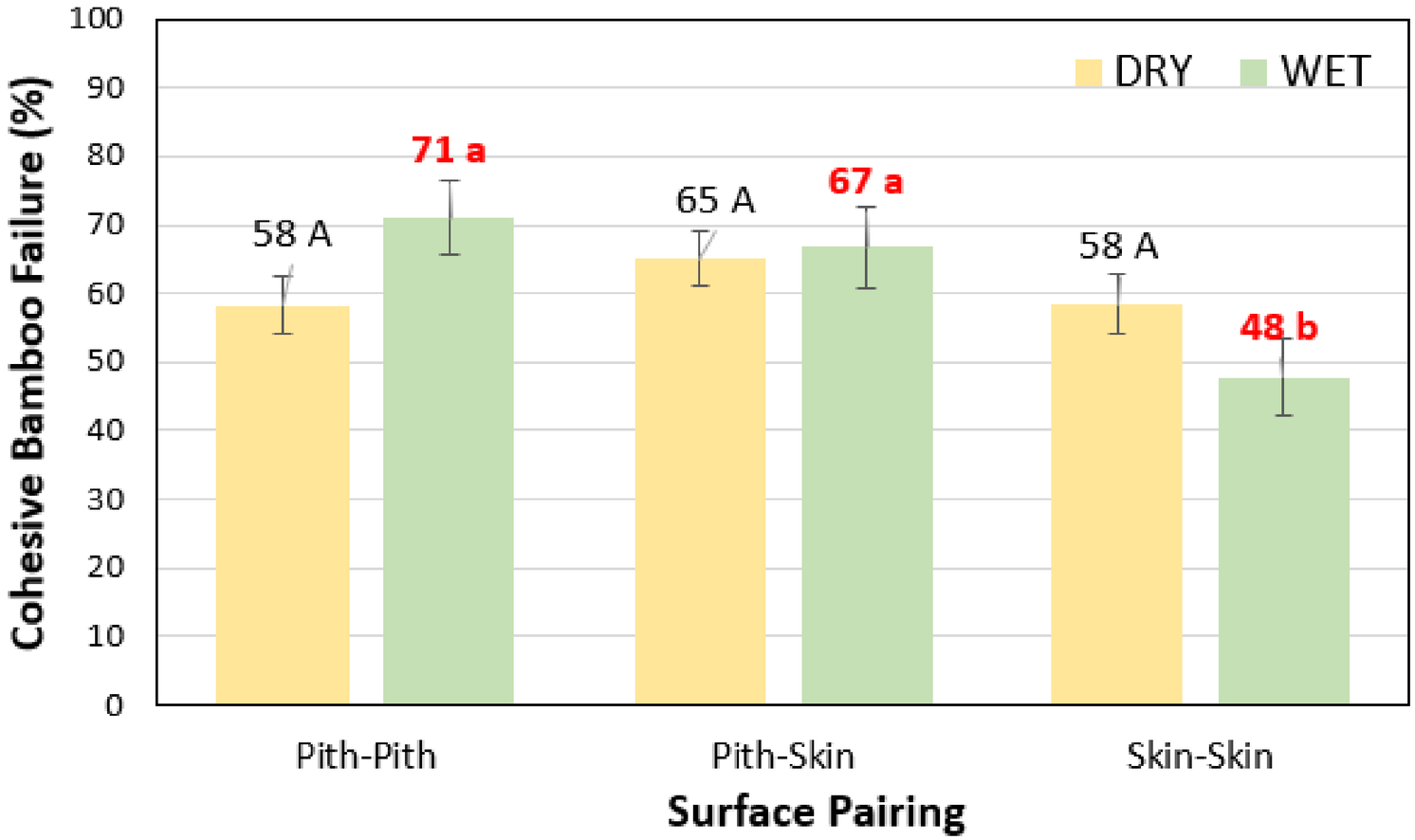


DSS:
S-S>S-P>P-P

WSS:
No significant difference

RESULTS

Surface Pairing

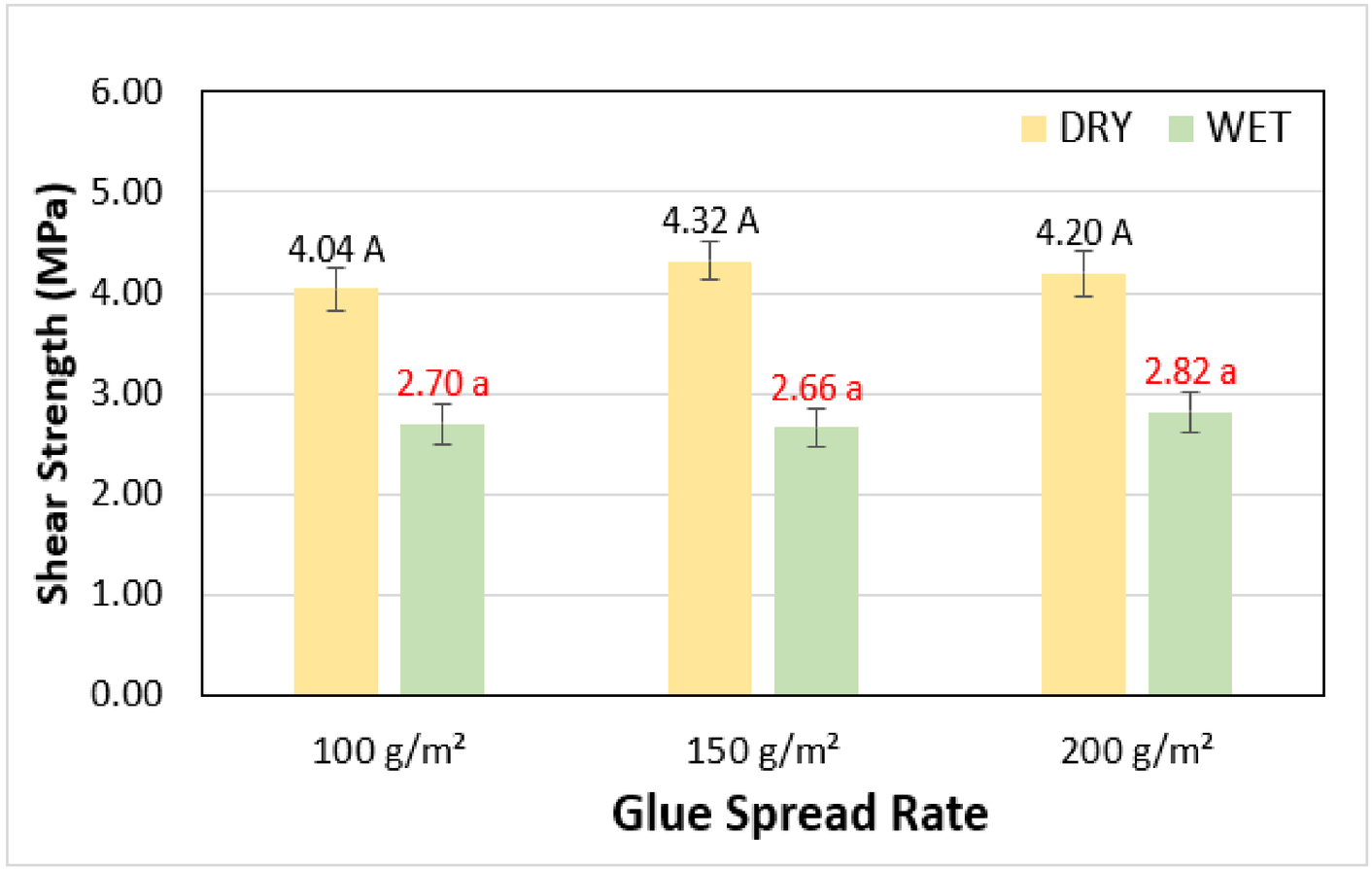


DBF:
No significant difference

WBF:
P-P=P-S>S-S

RESULTS

Glue Spread Rate



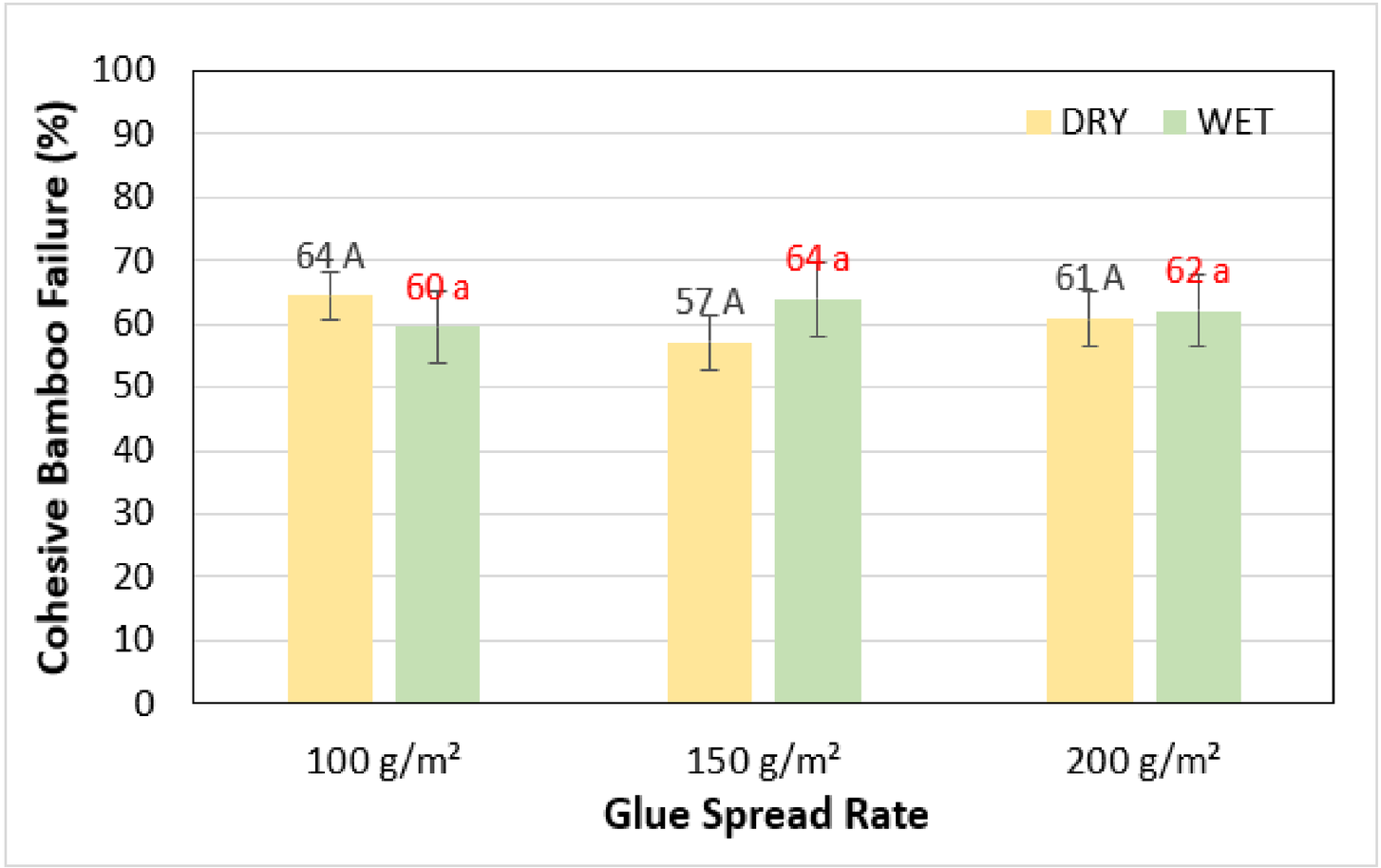
DSS:
No significant difference

WSS:
No significant difference

IMPLICATION:
reduction of lamination cost due to less amount of glue needed to bond bamboo strips

RESULTS

Glue Spread Rate



DBF:
No significant difference

WBF:
No significant difference

Application in BMI Making

Bamboo Lamination in BMI Making

Application in BMI Making

Bamboo Lamination in BMI Making

Application in BMI Making

Bamboo Lamination in BMI Making

Conclusions

Adhesive

- The gluebond strength performance of the four adhesives used in the study shows that PUR is the strongest in the dry shear test followed by PF, and lastly by PVAc-D3/UF.
- For the wet shear test, PUR and PF are the top performers, followed by UF.
- PVAc-D3 is the weakest and does not pass the standard requirement for the gluebond strength for the wet shear test.

Conclusions

Surface Pairing

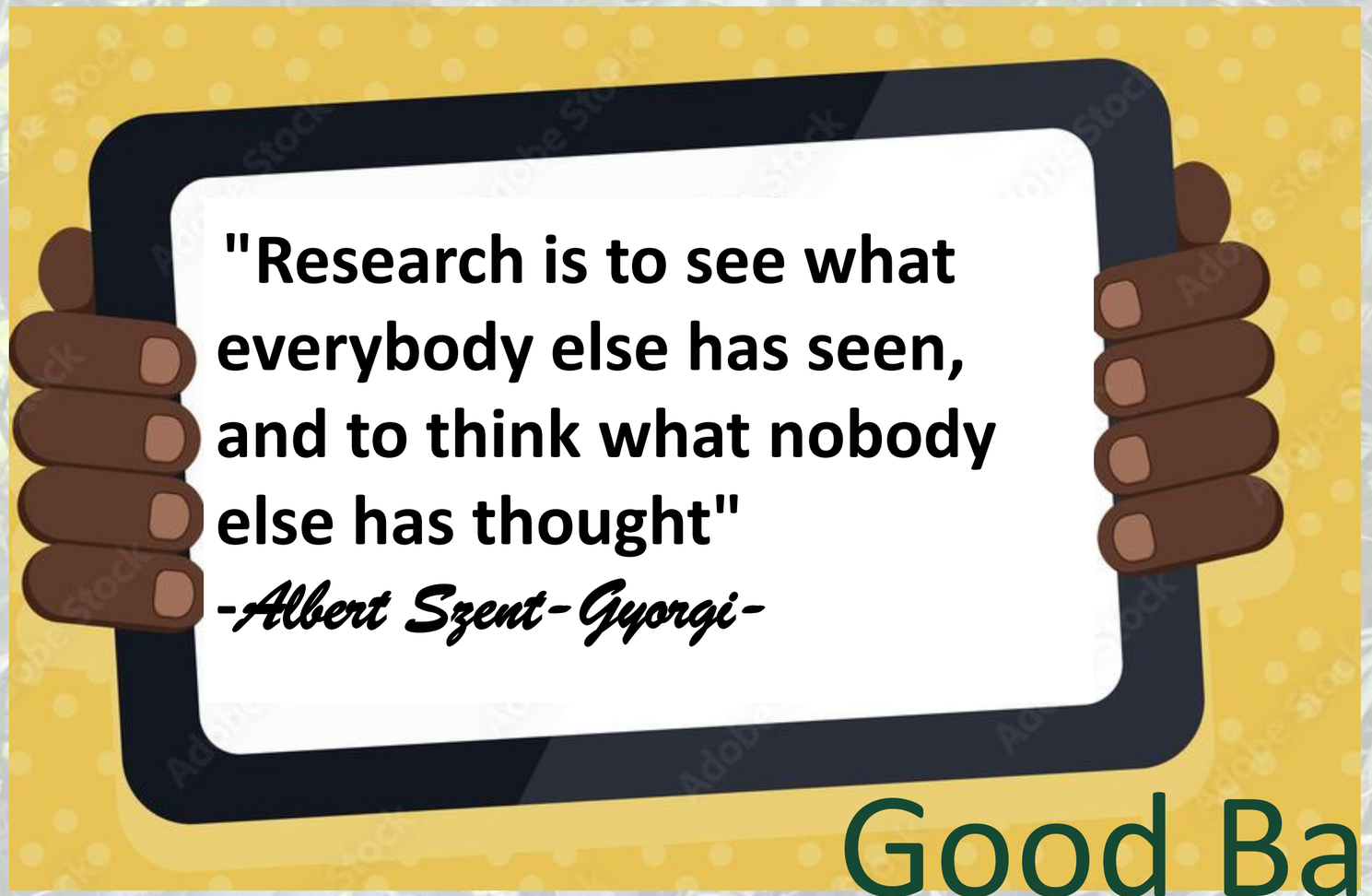
- Skin-skin (outer-outer) is the best surface combination, followed by pith-skin (inner-outer). Pith-pith (inner-inner) is the least desirable.
- It can be inferred that given a piece of engineered bamboo, failure could occur at the weakest link, which is the pith-pith bond.

Conclusions

Glue Spread Rate

- Glue spread rate generally does not influence the bond strength of PUR, PF and UF. Even at 100 g/m², these three adhesives can produce a strong gluebond that would pass the minimum standard requirement.

- PVAc-D3 requires a higher glue spread rate to cover the surface of the adherend due to its poor wettability as evidenced by its higher contact angle.



Good Bamboo Day to ALL. Thank You!