Architectural Bamboo in the Age of Digital Fabrication



The American Institute of Architects | Continuing Education Series Author: Smith & Fong Company plybooo

Architectural Bamboo in the Age of Digital Fabrication



The American Institute of Architects | Continuing Education Series Author: Smith & Fong Company



- San Francisco Based Manufacturer of Sustainable building materials in Bamboo and Palm.
- Founded in 1989, we were early pioneer in the development of the bamboo lamination process.
- First Manufacturer to create Bamboo Plywood "Plyboo", and first company to bring bamboo flooring to the American market in 1993.
- First to achieve FSC certification for Bamboo Plywood and Flooring in 1996.
- First to achieve Life Cycle Analysis for Bamboo and EPD 2017.

LEARNING OBJECTIVES

- 1. Understand the manufacturing process, construction and environmental properties (Life Cycle Analysis) of architectural bamboo panel.
- 2. Understand the set-up, tooling and machinery and techniques associated CNC milled bamboo panels.
- 3. Understand the process of fire rating and manufacturing acoustical products utilizing CNC milled architectural grade bamboo panels.
- 4. Understanding specify CNC milled bamboo panels including environmental, fire rating, acoustical and architectural grade bamboo requirements.

PROGRAM REGISTRATION

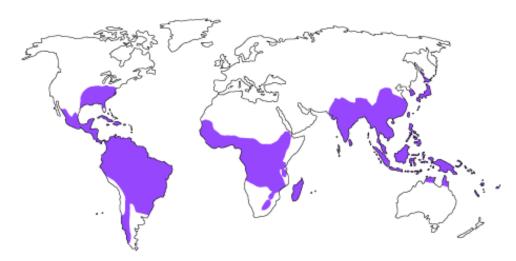
McGraw Hill construction is a registered provider with the American institute of architects continuing education systems. Credit earned on completion of this program will be reported to CES Records for AIA members. Certificated of completion for non-AIA members are available.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods and services will be addressed at the conclusion of this presentation.



GENERAL FACTS

- 1300 species of bamboo
- Grows through the world in a wide range of environments
- Sizes range from shrub to 120 feet
- Grows rapidly, reaching rate of 1 inch per hour
- Sequesters up to 70% more carbon per year than a hardwood forest (source: World Wildlife Fund)



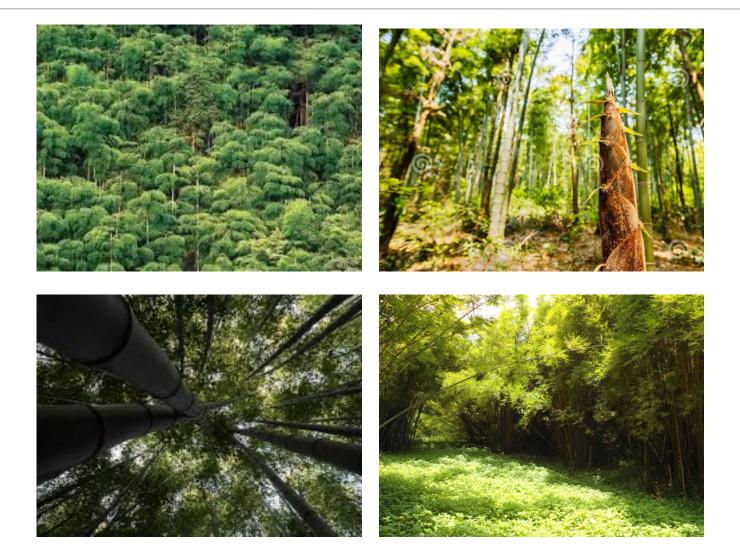
MOSO BAMBOO: FORESTRY



MOSO BAMBOO: FORESTRY



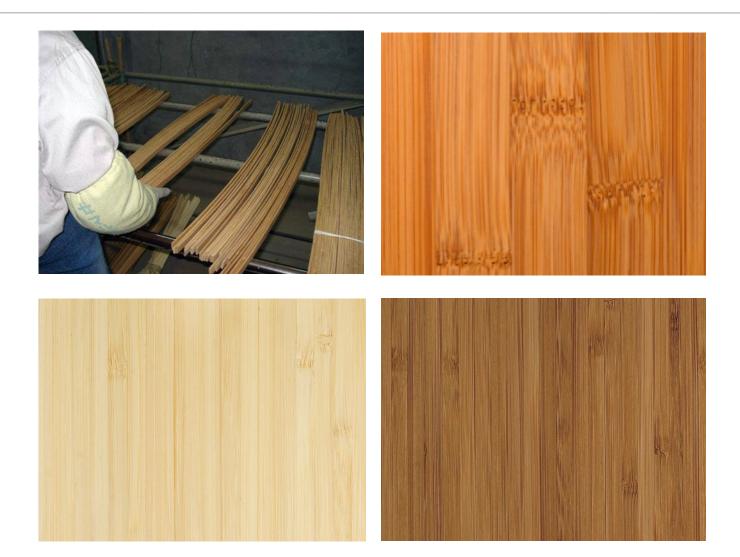
MOSO BAMBOO FORESTRY



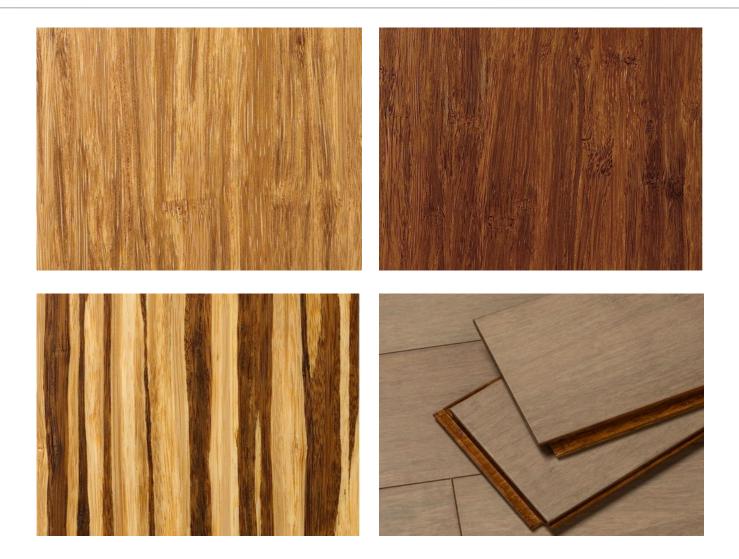
BAMBOO MANUFACTURING



BAMBOO LAMINATION



BAMBOO STRAND



• <u>US GREEN BUILDING COUNCIL'S LEED 3.0</u>

- MRc6: Rapidly Renewable Materials
- MRc7: Certified Wood and Bamboo
- IEQc4.4: Low Emitting Materials (Plywood and Veneer)
- IEQc4.3: Low Emitting Materials (Floor Score Certified)
- <u>LEED 4.0</u>

• <u>MRc4 Material Ingredients: Disclosure and</u> <u>Optimization</u>

Disclosure: An HPD can contribute as a floor, wall, ceiling or furniture material to the 20 products from at least 5 manufacturers that are required to achieve 1 point in this area.

• MRc2 Environmental Product Declarations: Disclosure and Optimization

Disclosure: An EPD (3^{rd} -party verified, product-specific EPD worth full credit) can contribute as a wall, ceiling or furniture material to the 20 products from at least 5 manufacturers that are required to achieve 1 point in this area.

• MRc3 Sourcing of Raw Materials Disclosure and Optimization

Disclosure: FSC certified products can contribute as a floor, wall, ceiling of furniture material to the 20 products from at least 5 manufacturers that are required to achieve 1 point in this area.

LEED CREDITS

EPD and Life Cycle Analysis for Architectural Bamboo Plywood

Environmental

Product

Declaration

In accordance with ISO 14025 for

Flat and Edge Grain Plyboo

Smith & Fong 475 Sixth Street San Francisco, CA 94103

Programm e	ASTM International https://www.astm.org/
Programme operator:	ASTM International
EPD registration number:	EPD 072
Approval date:	2017-10-18
Vald untit	2022-10-18 (5 years)
Revision diate:	
Geographical scope:	Global





plyboo

Geographical Considerations

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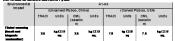


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Content declaration

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Scope and Boundaries of the Life Cycle Assessment

Cologies Maria Medianamia de los ante cayant analizatione de The Lik Cycle Anneaman (ICA) was performed accriting to Col 1400 and ISO 14044 and Podi Collegoys Palais (PCR) for Constraining Products and Services. This report is intended to full the requirements in Section 0 of the PCR. Additional debits can be found in the Pyboo LCA report, whi currents in greater datail the study goal and scope, investory analysis, results and interp

Please wie: The Bousant's separator and designation art used Broughout the EPD and LCA report use SI siyle (Explicit version), will a can marepresenting the Bousson's separator and a period representing the stock at mark.

Declared Unit

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System Boundary

ntal Product Declaration (EPD) is made for "Craille to Gale" according to EN 15804 This Err nal includes aloges A1 Brough A3 (non-residue, transportation, and manufacturing) of Module A of Construction Singer). Figure 1 presents the system to



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Parameter	Uncarved Plyboo, China	Carved Plyboo, US	Parameter unit expressed per kgof final product ideclared unit
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LCA Modules

The data presented in this EPD refer to the declared modules and form the basis for further calculations. All provided values are based on the declared pro-

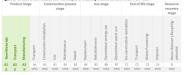
The European norm EN 15804 is based on four distinct modules relating to the lifecycle phases of a building material including the following:

- Module A: Production and Construction Stage
- Module C: End of Life Stage; and Module C: End of Life Stage; and Module D: Environmental Effects Outside of the System Boundary.

Figure 2 presents the stages within each module. This study is a 'cradie to gate' assessment, according to EN 15604, which includes stages A1 through A3 of Module A (shown highlighted in gree on the table below). The information provided in this EPD is aggregated for modules A1 through A3.

The products reference service life (RSL) is not specified because the study is 'cradie to gate' and also The publics elements are not an environment of the (Visco) is not specified declarate and the study is of cable if U given and and because there is a wide range of applications for flat and edge grain Phyloco products. Thus downstream life cycle stages are not included since they would be difficult to quantify given the wide range of product applications and uses.

Figure 2. Division of the modules over the lifecycle of a building material as determined in EN 15804 End of life stap



plyboo

Waste Production

Waste Type	Unit	Quantity, expressed per kg of final product (declared unit)			
		Uncarved Plyboo, China	Carved Plyboo US		
Non-hazardous waste	kg	0.1	0.4		
Hazardous waste	kg	0	0		
Radioactive waste	kg	0	0		

Interpretation of the Life Cycle Assessment

The environmental impact potential results represent the average environmental performance for a The environmental impact potential results represent the environment approximate for an environmental approximate provide a set of the environmental period or the environmental period or dimension and product weight. The dedinent out, *i.e.*, it klappen (b) of final bandword products is the dimension and product weight. The dedinent out, *i.e.*, it klappen (b) of final bandword products and the set of the set of the set of the environmental lenger of the on-inductional fiber or degram in photos as listed in the set setting and setting the set of the environmental lenger and products and the or degram and the product and the setting and the setting and the setting and the environmental lenger and the setting and the environmental lengers. The setting and the environmental lengers are beneficial fiber and environmental lengers are constant and the environmental lengers. The setting are beneficial to the environmental lengers are constant and the environmental lengers are beneficial to the environmental lengers are constant and the environmental lengers are beneficial to the environmental lengers are constant and the environmental lengers are beneficial to the environmental lengers are benefi

The dominant contributor to global warming for uncarved plyboo is steam generation, produced via The dominant contributor to global varining for uncreased physics is stain generation, inpolacies 400 supportantly 2000 and 2000

The key contributors to other environmental impact categories that are included in this study for carved and carved plyboo are summarized as follows:

- For uncarved Plyboo, the main contributors vary by impact categories using TRACI and CMI as follows:
- Steam is the main contributor for eutrophication (CML) and photochemical ozone
- formation (TRACI and CML); Electricity is the main contributor for ozone depletion (TRACI), acidification (TRACI) eutrophication (TRACI), and depletion of abiotic resources (fossI) (TRACI and CML); o Adhesive is the main contributor for depletion of abiotic resources (elements) (CML);
- Transportation is the main contributor for ozone depletion (CML) and acidification (CML)
- For carved Plyboo, the main driver for the other impact categories using TRACI and CML is electricity from carving operations in Indio, CA, except for the following:

 Packaging is the main driver of depletion of abolich resources (elements) for CML

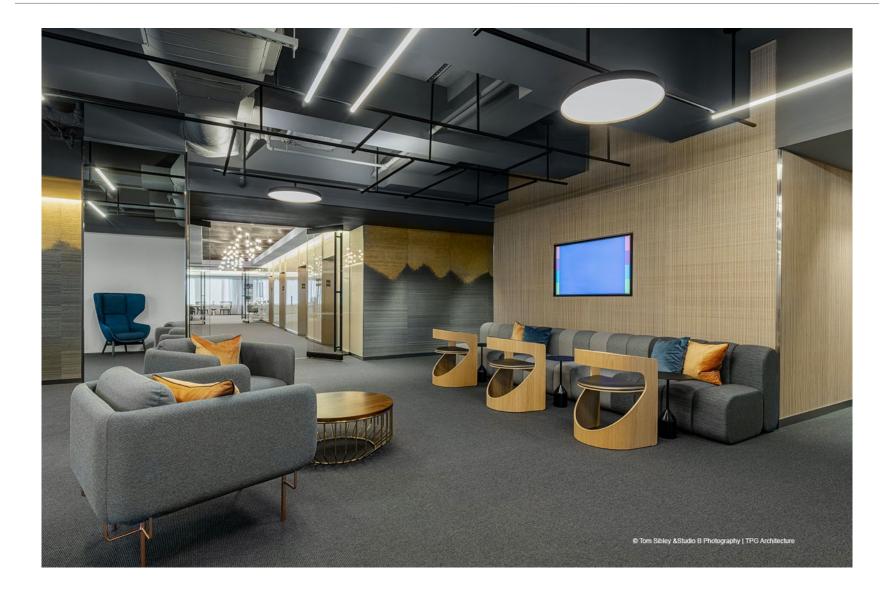


Programme-related information and verification

PCR:	PCR 2012:01 Construction products and Construction services, Version 2.01, 2016- 03-09		
PCR review was conducted by:	The International EPD® System operated by EPD International AB, Box 210 60, SE100 31 Stockholm, Sweden Contact: Martin Erlandsson, IVL Swedish Environmental Research Institute, martin.erlandsson@W.ee		
Independent verification of the declaration and data, according to ISO 14025:	 EPD process certification (Internal) EPD verification (External) 		
Third party verifier:	Thomas P. Gloria, Ph. D. Industrial Ecology Consultants 35 Bracebridge Rd. Newton, MA 02459-1728 t.djoria@industrial=ecology.com		
Accredited or approved by:	ASTM International		



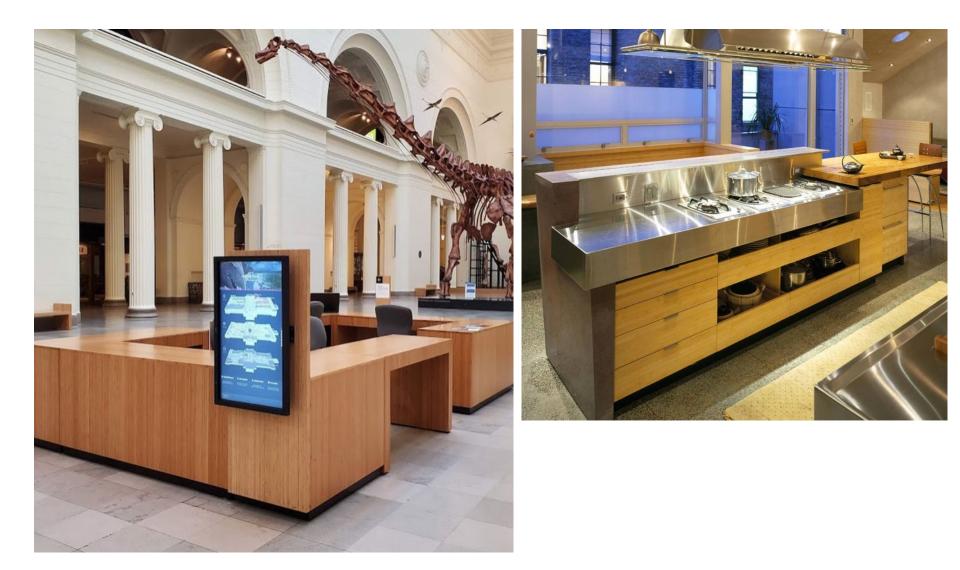








CABINETS AND MILLWORK



DOORS



DOORS | WALLS





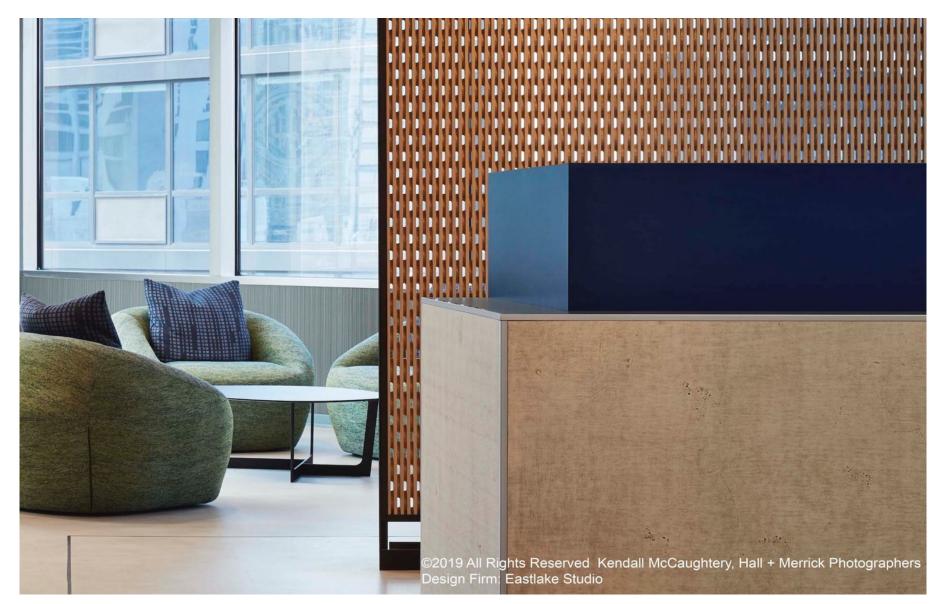
PERFORATED WALLS | CEILINGS



PERFORATED CEILINGS



DIVIDERS | LOBBIES



FURNITURE



BENEFITS OF ARCHITECTURAL BAMBOO PLYWOOD

- Bamboo Plywood that is cross laminated provides excellent stability and does not require edge banding
- Bamboo Plywood that is manufactured for the sole purpose of routing and therefore consistent in color and without voids
- Bamboo Plywood that is manufactured with a 3mm face and balanced allows for a durable wear layer ideal for commercial applications
- Bamboo Plywood that is pre-sanded and pre-finished is easier to work with and installation ready.
- When carved, an interplay between the face layer and revealed inner core creates a stunning visual effect.

CNC ROUTERS

FORM AND FUNCTION

- CNC router (Or Computer Numerical Control router) is a computer-controlled cutting machine related to the hand held router used for cutting various hard materials, such as wood, composites, aluminum, steel, plastics, and foams. CNC stands for computer numerical control.
- A CNC router typically produces consistent and high-quality work and improves factory productivity.
- Unlike a jig router, the CNC router can produce a one-off as effectively as repeated identical production. Automation and precision are the key benefits of CNC router tables.

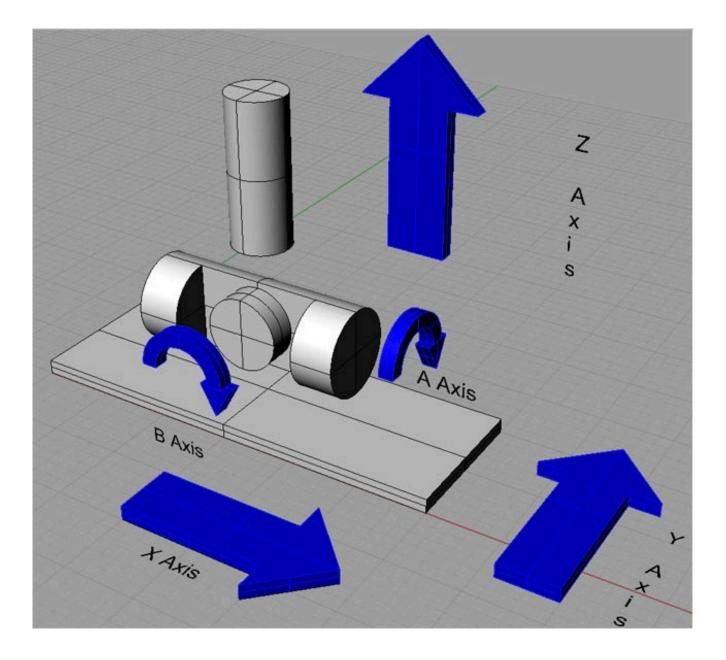
CNC ROUTERS

FORM AND FUNCTION

- Computer driven routing machine that provides precise multi-axis carving of many materials by introducing a knife to a material that is secured to a vacuum secured bed.
- Depending on its level of sophistication, CNC Machines are able to cut on 3 or 5 axis's (examples of cutting on axis)
- 5 axis machines while more expensive can offer more complex and dimension cutting



















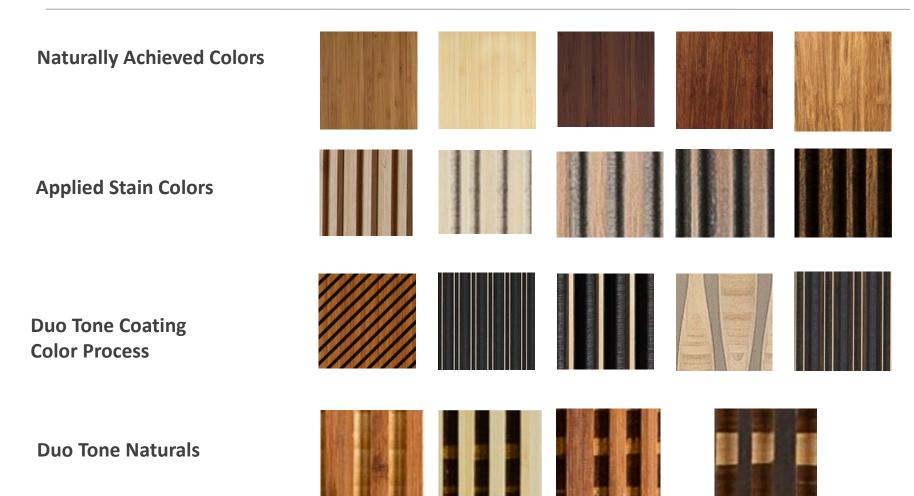


BAMBOO PANELS AND CNC ROUTING

Once carved, these panels reveal the multiple layers and strips that it is constructed from.



COLORATIONS AND STAINS (Examples)



FIRE RATING



CLIENT: SMITH & FONG Test Report Number : RJ4943-3 Date: September 2, 2016 Page 4 of 7

SUMMARY OF ASTM E84 RESULTS:

Because of the possible variations in reproducibility, the results are adjusted to the nearest figure divisible by 5. Smoke Density values over 200 are rounded to the nearest figure divisible by 50.

In order to obtain the Flame Spread Classification, the above results should be compared to the following table:

NFPA CLASS	IBC CLASS	FLAME SPREAD	SMOKE DEVELOPED
A	A	0 through 25	Less than or equal to 450
В	В	26 through 75	Less than or equal to 450
С	С	76 through 200	Less than or equal to 450

BUILDING CODES CITED:

1. National Fire Protection Association, ANSI/NFPA No. 101, "Life Safety Code"

2. International Building Code, Chapter 8, Interior Finishes, Section 803.

ASTME 84 CLASS A (Bamboo Strand Core)



FIRE RATING

CLIENT:	SMITH & FONG 475 6th Street San Francisco, CA 94103			
Test Report Numb	er : RJ4943-2	Date:	September 2, 2016	
SAMPLE ID:	The client identified the following test material as: Plyboo Linear 4. Thickness: 3/4 " inch. (See photo in Appendix)			
SAMPLING DETAIL:	Test Samples were submitted to the Laboratory directly by the client. No sampling or sample preperation were observed by QAI staff.			
DATE OF RECEIPT:	Samples were received at QAI facilities on	August	25, 2016	
TESTING PERIOD:	August 31, 2016.			
AUTHORIZATION:	Testing was authorized by for proposal 16MB08052R1 signed August 5, 2016			
TEST REQUESTED:	Perform standard flame spread and smoke density developed classification tests on the sample supplied by the Client in accordance with ASTM Designation E84-16, "Standard Method of Test for Surface Burning Characteristics of Building Materials". The foregoing test procedure is comparable to UL 723, ANSI/NFPA No. 255, and UBC No. 8-1.			
TEST RESULTS:	Flame Spread Smo	oke Developed		
	20	30		
CONCLUSION:	When tested in accordance to ASTM E84-16 the tested material resulted in a Class 'A'. Detailed test results are presented in the subsequent pages of this report			

ASTME 84 CLASS B (Bamboo Ply Core)



FIRE RATING

CLIENT: SMITH & FONG 475 6th Street San Francisco, CA 94103

Test Report Number : RJ4943-3		Date	e: September 2, 2016		
SAMPLE ID:	The client identified the following test material as: Plyboo Liner Line 7. Thickness: 3/4 " inch. (see photo in Appendix)				
SAMPLING DETAIL:	Test Samples were submitted to the Laboratory directly by the client. No sampling or sample preparation were observed by QAI staff.				
DATE OF RECEIPT:	Samples were received at QAI facilities on	: Au	igust 25, 2016		
TESTING PERIOD:	August 31, 2016.				
AUTHORIZATION:	Testing was authorized by Stacy Willard for August 5, 2016	or proposal 16ME	B08052R1 signed		
TEST REQUESTED:	Perform standard flame spread and smoke density developed classification tests on the sample supplied by the Client in accordance with ASTM Designation E84-16, "Standard Method of Test for Surface Burning Characteristics of Building Materials". The foregoing test procedure is comparable to UL 723, ANSI/NFPA No. 255, and UBC No. 8-1.				
TEST RESULTS:	Flame Spread Sm	oke Developed			
	65	105			
	* Note: Due to excessive heat production, the test was terminated early as noted. Had the test continued for the normal 10 minute period, the flame spread value would have remained unchanged. The Smoke value has been estimated based on the last reading				
CONCLUSION:	When tested in accordance to ASTM E84- 'B'. Detailed test results are presented in t				

FIRE RATING



CLIENT: SMITH & FONG Test Report Number : RJ4943-3 Date: September 2, 2016 Page 4 of 7

SUMMARY OF ASTM E84 RESULTS:

Because of the possible variations in reproducibility, the results are adjusted to the nearest figure divisible by 5. Smoke Density values over 200 are rounded to the nearest figure divisible by 50.

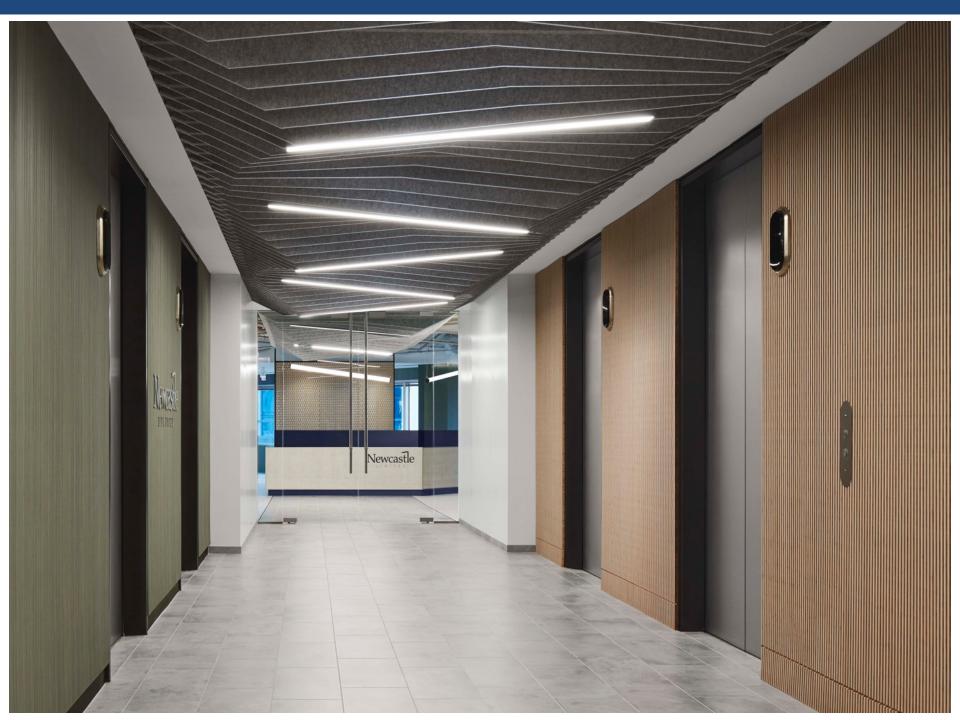
In order to obtain the Flame Spread Classification, the above results should be compared to the following table:

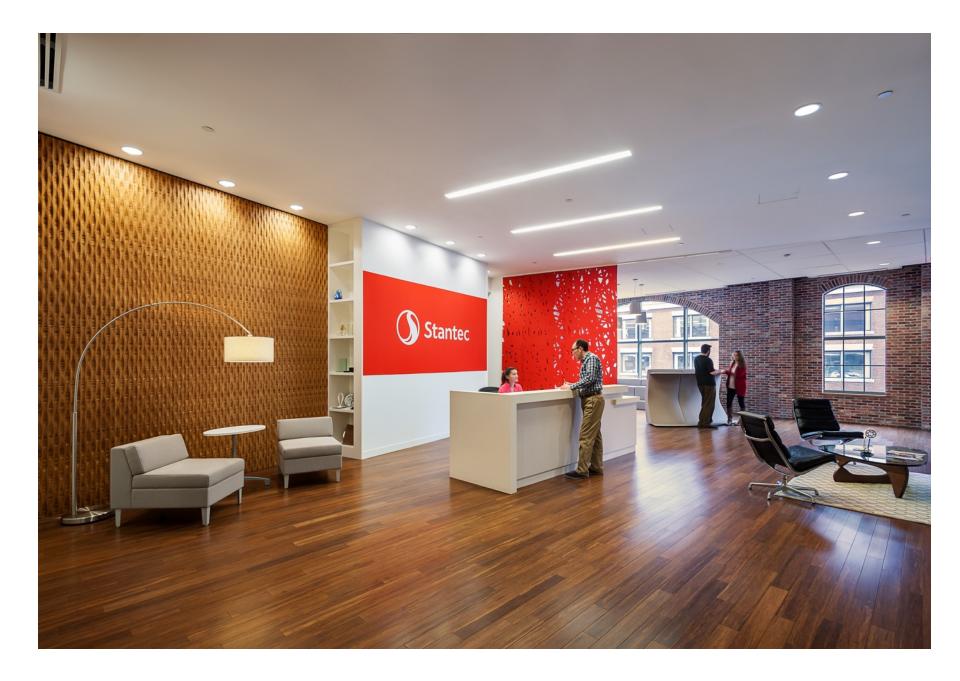
NFPA CLASS	IBC CLASS	FLAME SPREAD	SMOKE DEVELOPED
A	A	0 through 25	Less than or equal to 450
В	В	26 through 75	Less than or equal to 450
С	С	76 through 200	Less than or equal to 450

BUILDING CODES CITED:

1. National Fire Protection Association, ANSI/NFPA No. 101, "Life Safety Code"

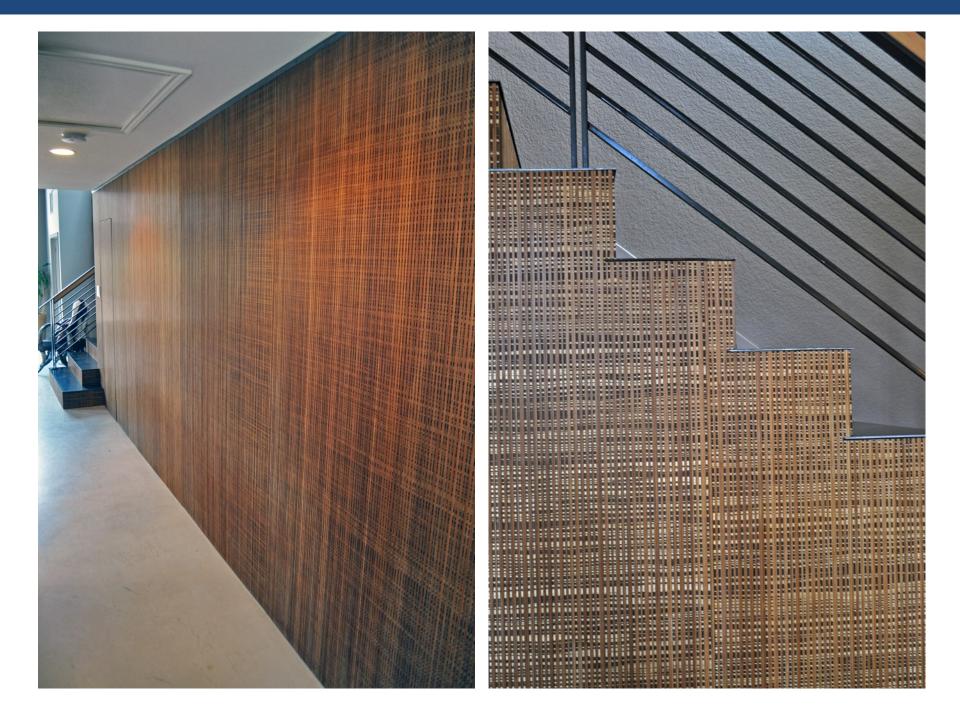
2. International Building Code, Chapter 8, Interior Finishes, Section 803.





CARVING GUIDELINES SPECIFIC TO BAMBOO PANELS

- Panels can be carved primarily with the grain and may be carved against the grain in some cases.
- Graphic imagery, linear, sculptural and perforated carving are all possible.
- Up to 50% of material can easily be removed from panels without losing material integrity.
- Highly flexible, material will conform to a radius of up to 2'



BAMBOO PANELS AND CNC ROUTING

- Bamboo Panels manufactured specifically for carving will have consistent color, without voids and may contain any combination of cores and faces.
- Material may easily be customized due to various carving, stacking and coloration techniques





CARVING GUIDELINES SPECIFIC TO BAMBOO PANELS

- Radius inside corners as well as hard corners are possible
- Varied depth up to $\frac{1}{2}$ " and widths are possible as little as 1/4"
- Panels may be stacked to many times their size to create greater mass.
- Custom patterns are often just as fast or cost effective achieve as standard options due to cost being relative to time on the CNC
- Consider "scaling up" patterns to control cost

MATERIAL+ FABRICATION COST Approx \$6 per SF

Non carved bamboo Plywood:

- Organically carved and linear non perforated: Approx \$25-27 per SF
- Perforated, Acoustical Panels: Approx \$35-\$45 per SF
- Modular Design System: Approx.
 \$35 per SF



Product Info

Video

Linear Line Panel Style LL5

Specifications CSI 3-part specification - Linear Line Collection Core Composition: RealCore™ Technology Color: Amber Material: 100% Bamboo Size: 3/4" x 473/4" x 953/4" Metric:19mm x 1213mm x 2432mm Weight: 90 lbs Surface Texture: Prefinished or Unfinished Fire Resistance Classification: Class C (Class B available) Emission Testing: ASTM-D6007-02: Formaldehyde Concentration in air from Wood Products, small chamber testing Result: 0.004ppm (surpasses CARB II standards of 0.05ppm and ULEF standards of 0.04ppm) **BP-V4896RN/LL5** Installation Guide

Specs

Linear Sound Collection





Sound Collection



Linear Collection



Reveal Collection





Product Info

Video

Linear Line Panel Style LL2

Specs

Specifications

CSI 3-part specification - Linear Line Collection Core Composition: RealCore™ Technology Color: Amber Material: 100% Bamboo Size: 3/4" x 473/4" x 953/4" Metric: 19mm x 1213mm x 2432mm Weight: 90 lbs Surface Texture: Prefinished or Unfinished Fire Resistance Classification: Class C (Class B available) Emission Testing: ASTM-D6007-02: Formaldehyde Concentration in air from Wood Products, small chamber testing Result: 0.004ppm (surpasses CARB II standards of 0.05ppm and ULEF standards of 0.04ppm) BP-S4896VA/LL2: Installation Guide

Linear Sound Collection



Sound Collection



Linear Collection



Reveal Collection



500 E. 1998



Product Info

Video

Linear Sound Panel Design LS14F

Specs

Specifications

CSI 3-part specification - LinearSound Collection Sound Absorption: QuietWall™ Technology (Test Result) Core Composition: RealCore™ Color: Fog Material: 100% Bamboo Size: 3/4" x 473/4" x 953/4" Metric:19mm x 1213mm x 2432mm Weight: 80 lbs Surface Texture: Prefinished or Unfinished Fire Resistance Classification: Class C (Class B available) Noise Reduction Coefficient (NRC): avg. 0.70 Sound Transmission Class (STC): avg. 0.00 Emission Testing - CA Section 01350 Protocol: No VOC's with chronic REL's (reference exposure level) detected; passes office, school, and residential criteria BP-V4896A/LS14F: Carb Phase II Compatible Installation Guide

Linear Sound Collection



Sound Collection



Linear Collection



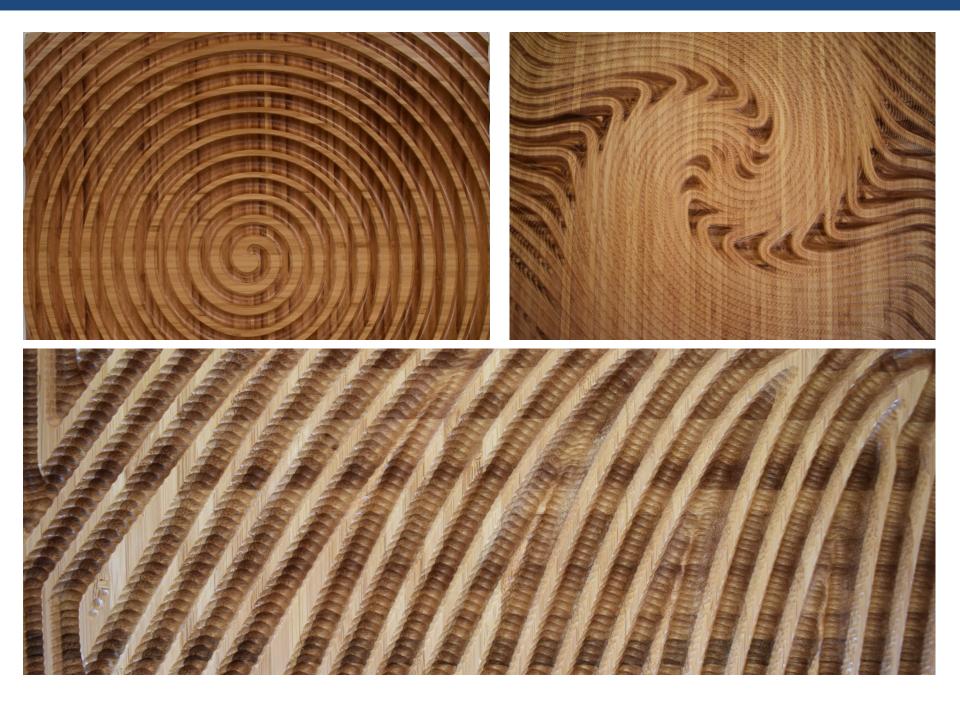
Reveal Collection



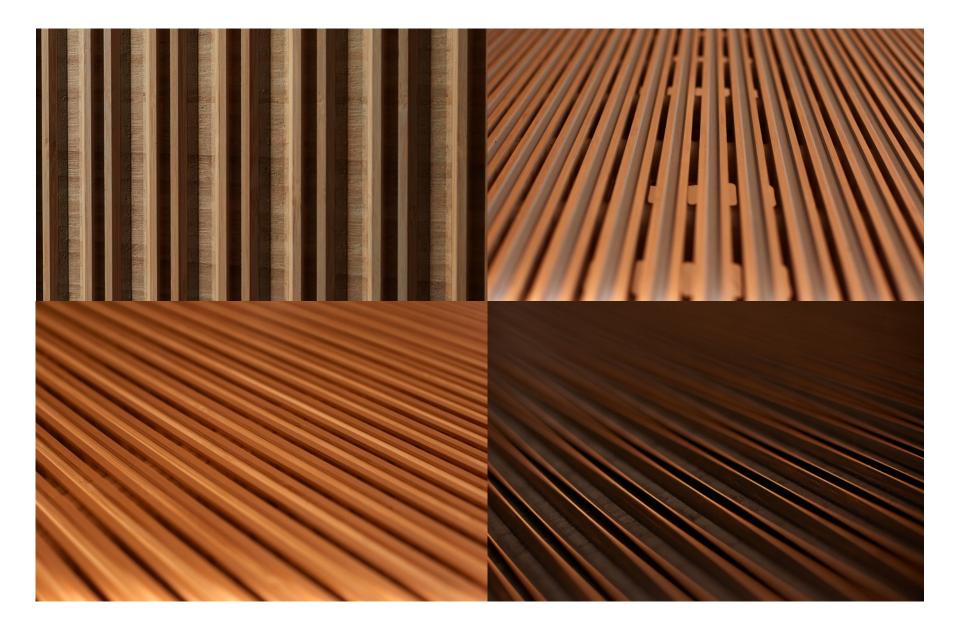
Palm Collection









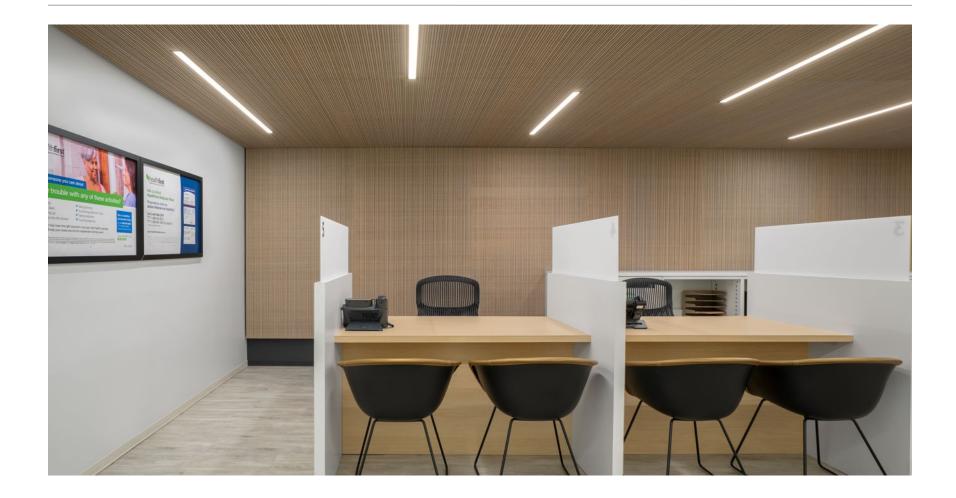




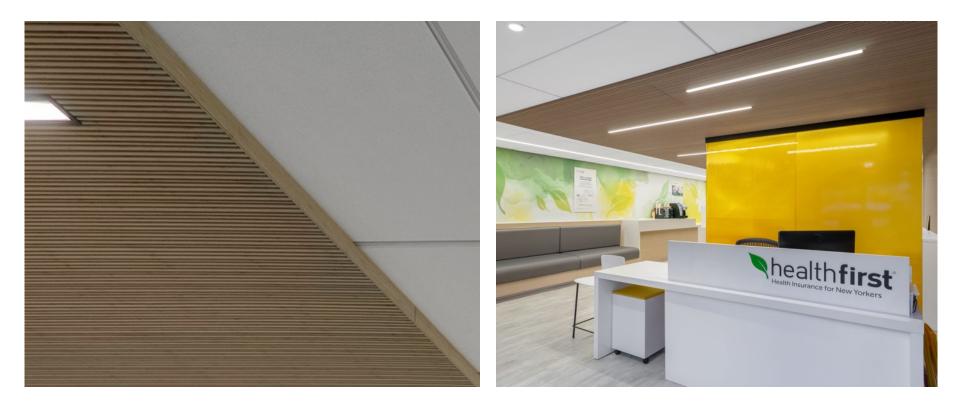


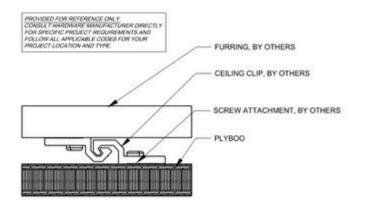


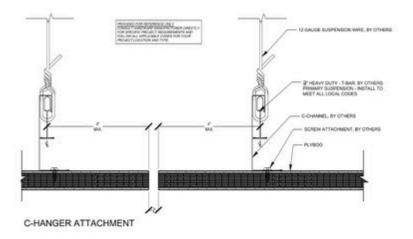
ACCOUSTIC CEILINGS



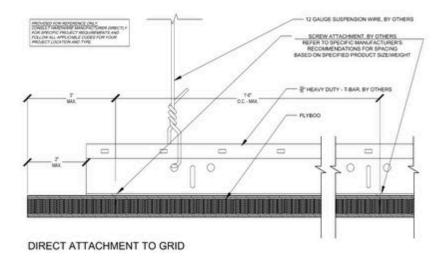
ACCOUSTIC CEILINGS

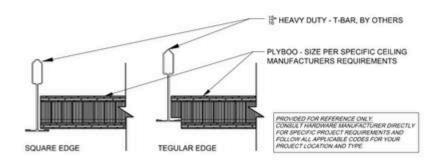






DIRECT MOUNT ATTACHMENT - OPTION 1





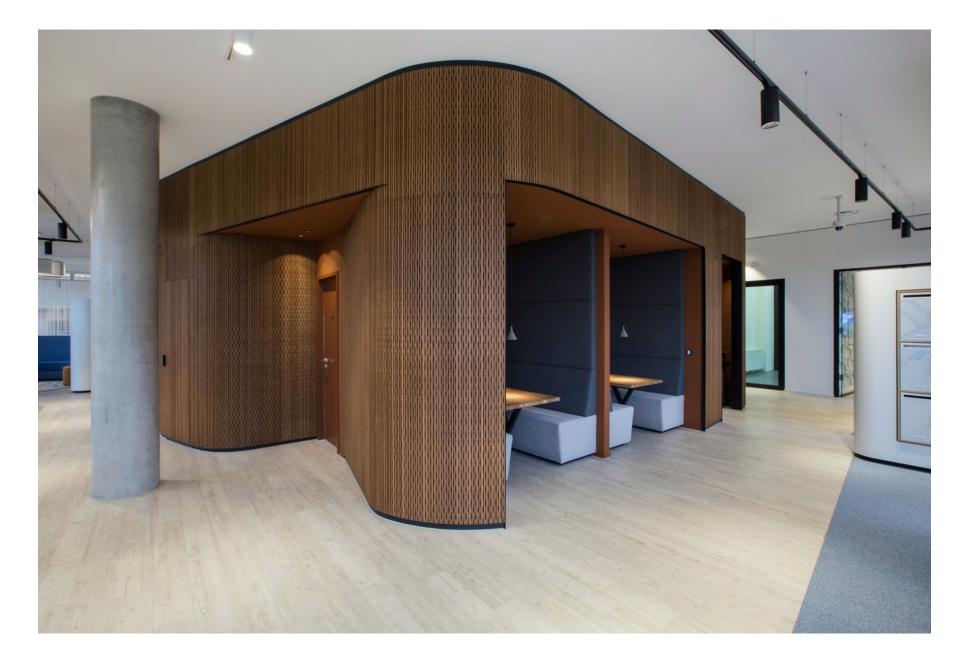


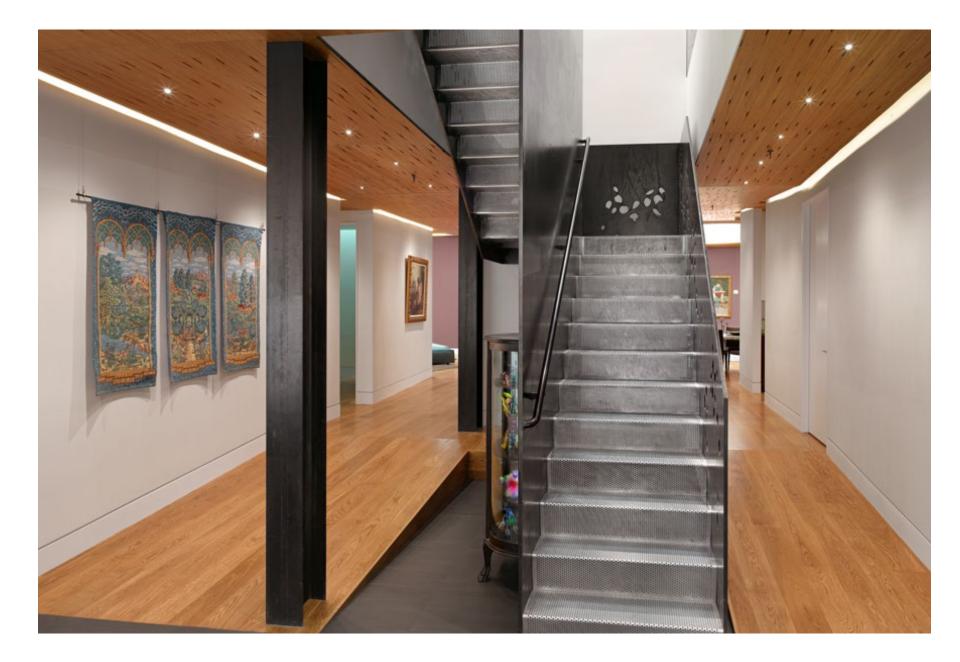
ARCHITECTURAL BAMBOO PANELS USED ACOUSTICALLY

- Panels can achieve acoustically absorptive properties by marrying a high performance pad behind a perforated decorative panel.
- Acoustical performance is rated using NRC (Noise Reduction Coefficient) averaging .70
- Absorptive elements may be placed behind (with air space) or attached directly to panels using adhesive
- Edges may be concealed using flange detail or left exposed
- Attachments for panels include z clip and C clips for ceiling and wall applications.

ARCHITECTURAL BAMBOO WITH PERFORATIONS CAN BEND







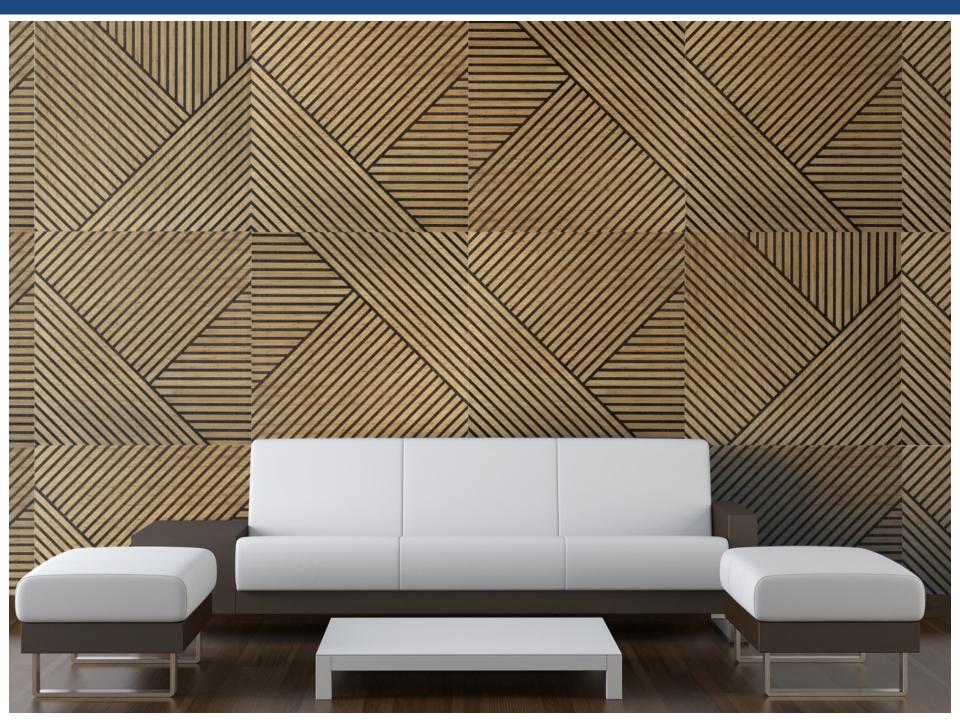


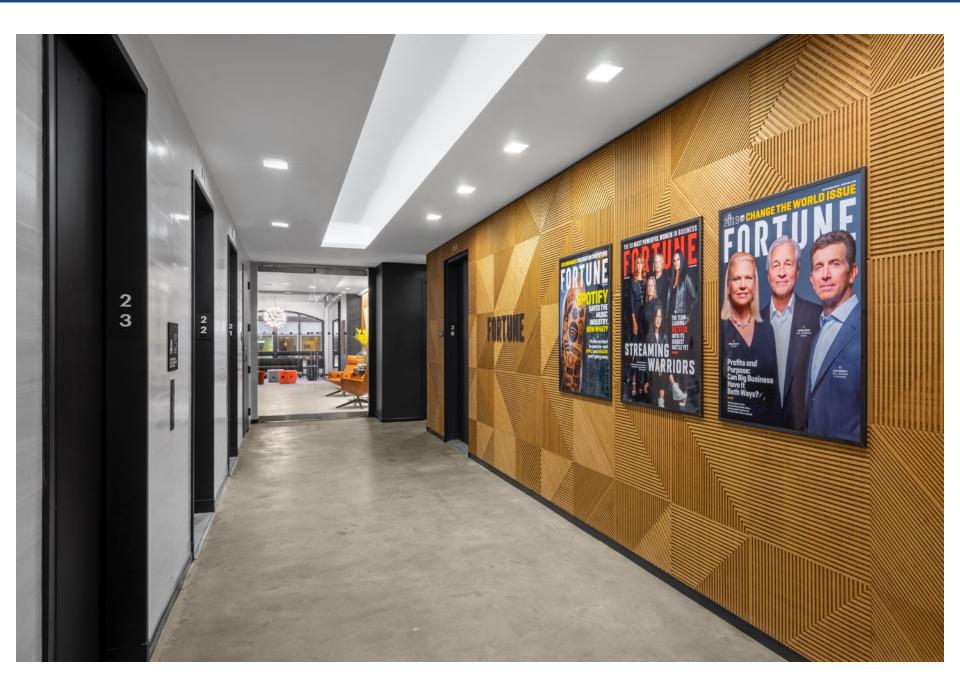
ARCHITECTURAL BAMBOO PANELS USED IN A MODULAR SYSTEM



BAMBOO PANELS USED IN A MODULAR SYSTEM

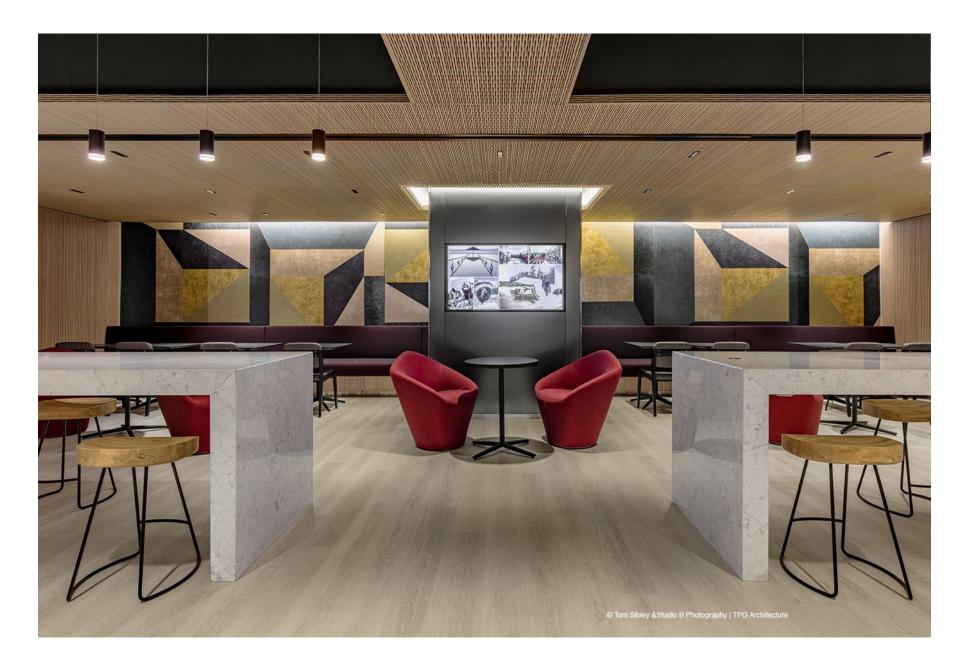


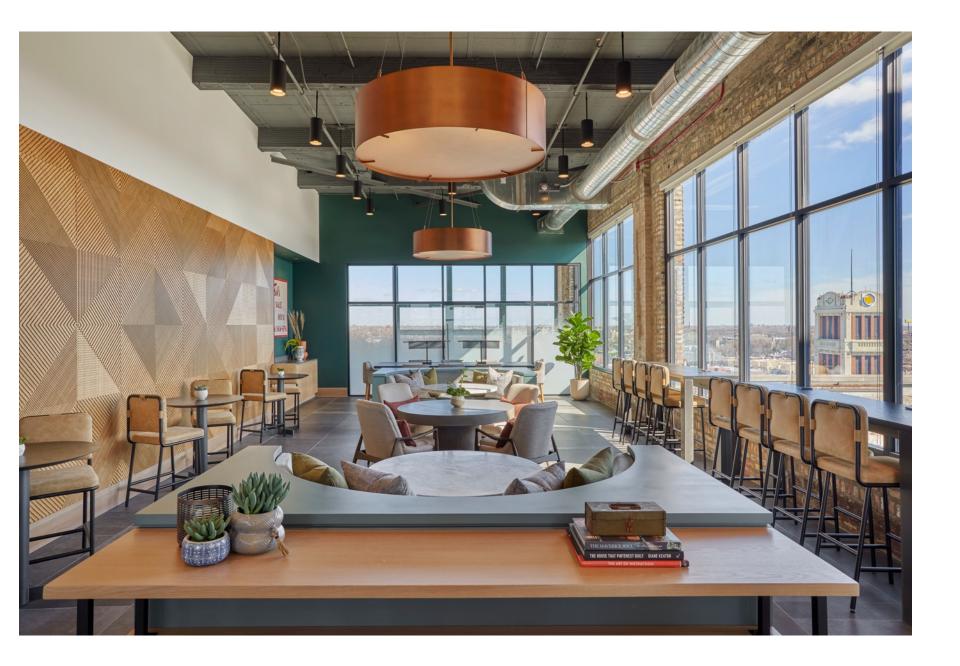


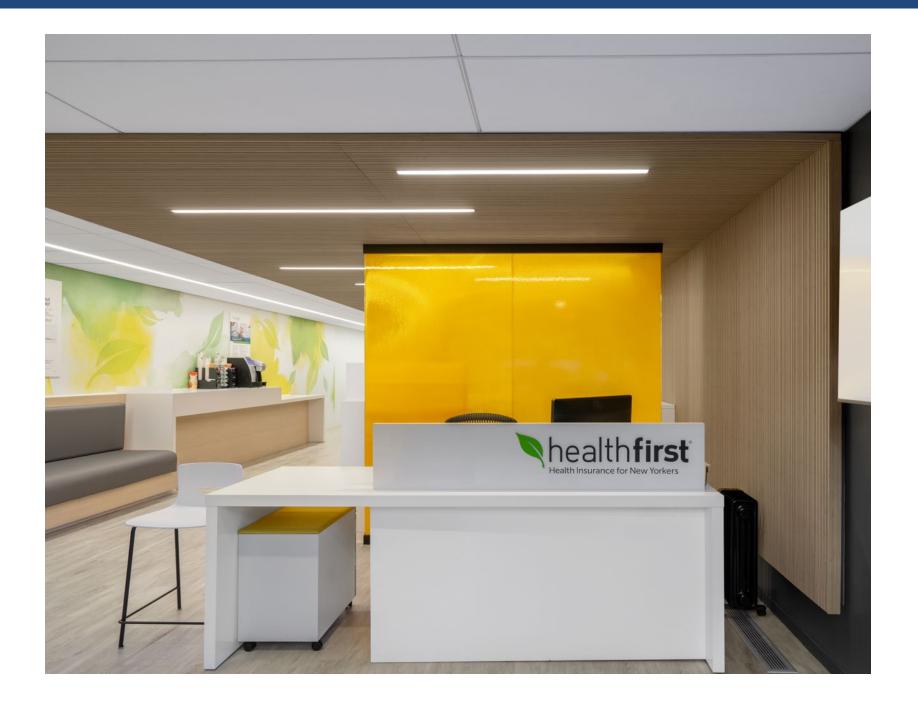


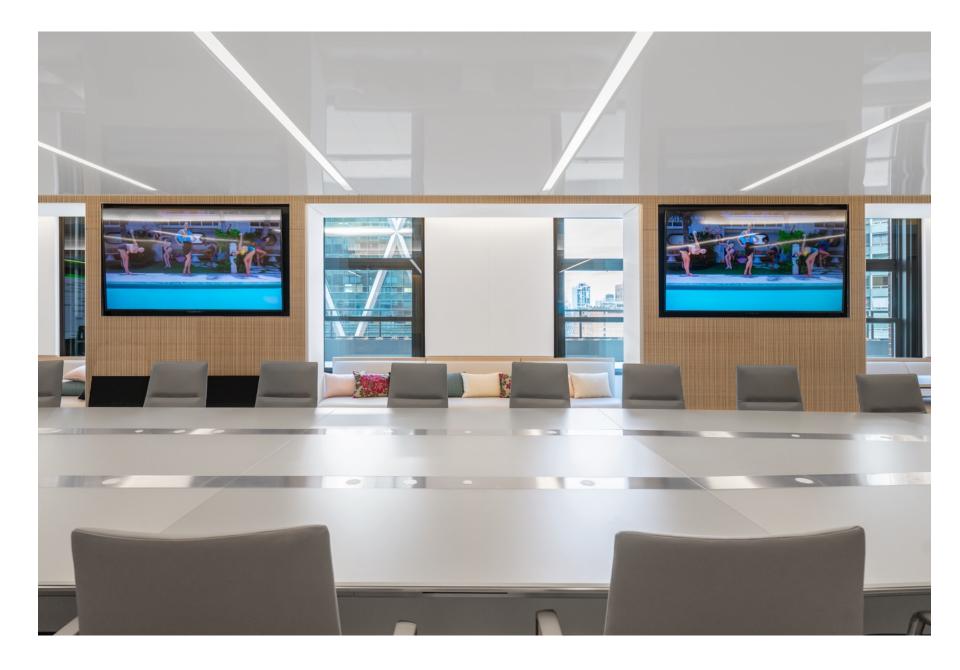


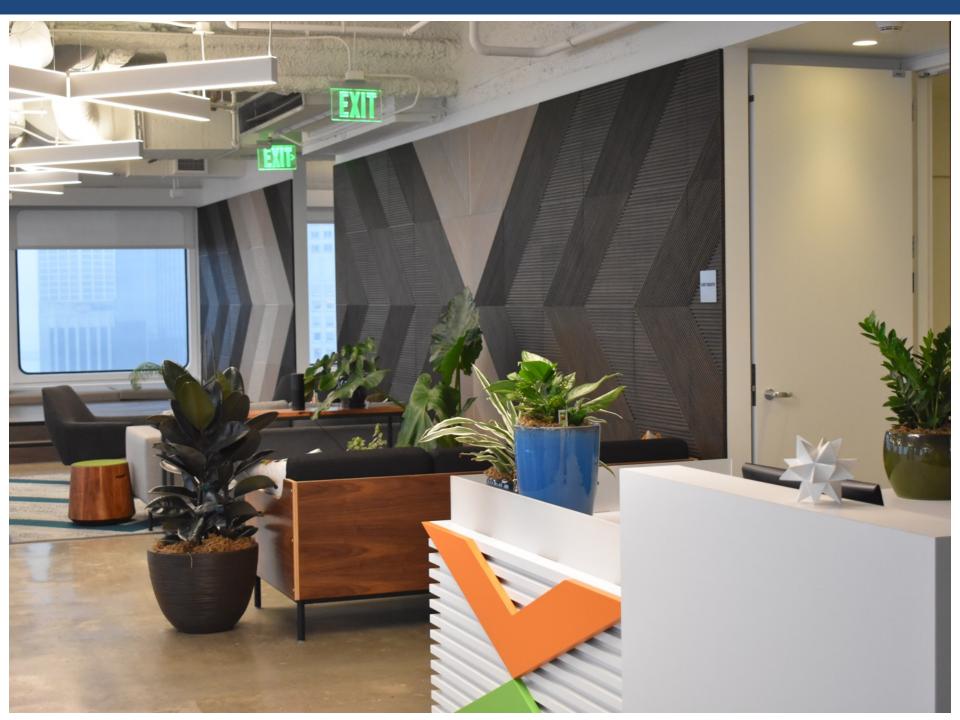


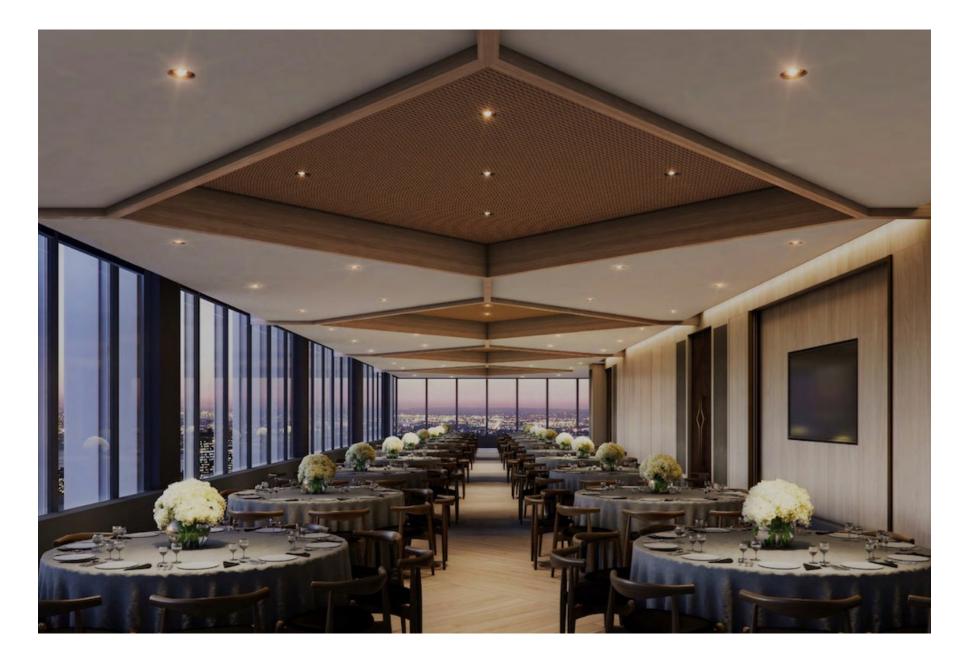












PLYBOO TIMELINE

- ∎ 2019 Louver™ Panels launch
- ∎ 2018 Launch Futura™ System
- 2017 Life Cycle Analysis and EPD
- ∎ 2017 Launch Fractal™ Wall System
- 2015 Linear Sound Panels for Acoustics
- 2014 Decorative Panels **Reveal**, Linear and Sound added to product line
- 2012 FloorScore all Flooring Products
- 2010 NAUF/FSC Strand Plywood
- 2008 FSC Certified Bamboo
- 2007 PlybooPure-CA Section 01350 Passed
- 2006 PlybooSport Sports Court Floor
- 2005 Neopolitan Strand Bamboo
- 2001 Durapalm Plywood and Flooring
- 2000 Strand Bamboo Flooring
- 1996 Bamboo Plywood
- 1993 Bamboo Flooring
- 1989 Pioneered Laminated Bamboo Technique



ARCHITECTURAL BAMBOO PANELS USED IN A MODULAR SYSTEM

https://design.plyboo.com/