PDS Basics: Fasteners

LASZLO HORVATH, PHD, CPLP

ASSOCIATE PROFESSOR
DIRECTOR, CENTER FOR PACKAGING AND UNIT LOAD DESIGN

DEPARTMENT OF SUSTAINABLE BIOMATERIALS
VIRGINIA TECH

VIRGINIA TECH

VIRGINIA TECH

Pallet Fastener Effect

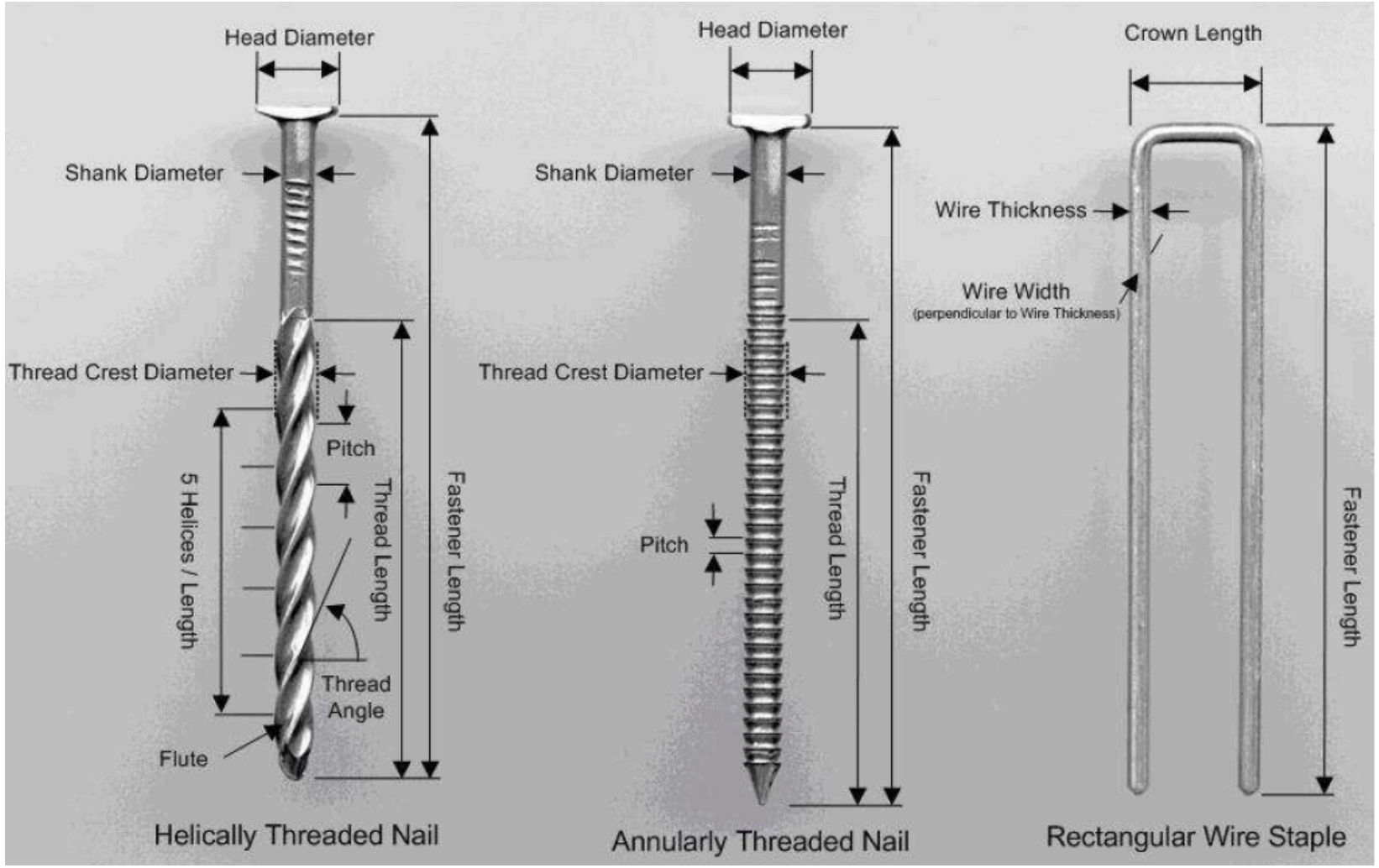
- When fasteners fail damage occurs
- The quality of pallet fastener affects
  - Pallet durability
  - Pallet strength and stiffness
- Pallet fasteners are only 5% of the pallet cost

Pallet Fastener Types

Pallet Fastener Types

- Helically Threaded Nails
- Twisted Square Wire Nails
- Annularly Threaded Nails
- Plain Shank Nails
- Staples (Round or Square Wire)

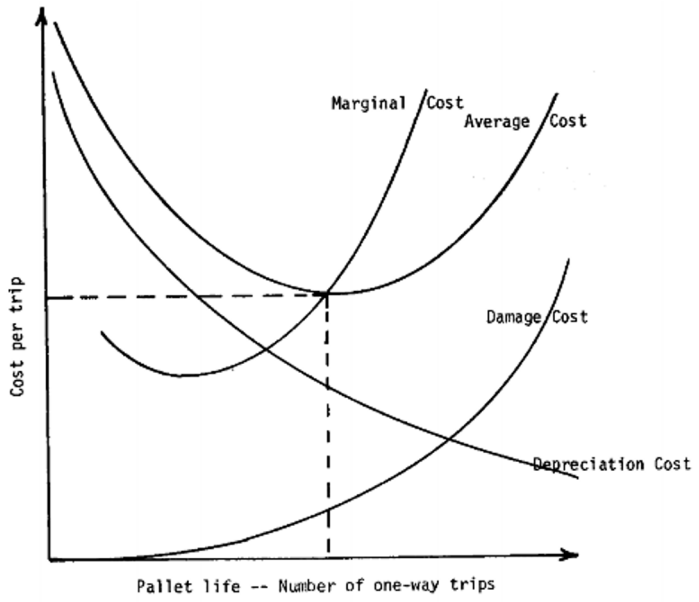
Fastener Dimensions



VIRGINIA TECH

Pallet Durability

Effect of Fastener Quality



- Durability prediction model
- Developed by Whitenack and Wallin (1982) based on the results of the Pallet Exchange Study in 1972.
- Model determined the economic life of the pallet based on
  - Purchase price
  - Depreciation
  - Cost of damage
    - **Severity of damage**
    - **Damage rate**
    - Economic factors related to pallet repair cost

Effect of Fastener Quality

Factors Affecting Durability

- F(1) - factor for fastener-withdrawal resistance
- F(2) - factor for fastener-shear resistance
- F(3) - factor for connection -splitting resistance
- F(4) - factor for shook quality
- F(5) - factor for selective shook-quality placement
- R(1) - facture for flexural strength of stringers
- R(2) - facture for flexural strength of decks
- R(3) - factor for deck construction
- R(4) - factor for material handling equipment

Fastener quality effect

Fastener location effect

Durability Analysis in PDS

Pallet Durability Analysis

Pallet Service Life Analysis

The **Pallet Service Life Analysis** simulates a series of forces and impacts applied to the pallet during each handling cycle. The frequency and severity of these impacts are estimates based on laboratory measurements, warehouse observations, and the Virginia Tech FasTrack Handling Cycle. The resistance to damage and the damage level requiring component repair or replacement are based on laboratory testing and the NWPCA Uniform Standard for Wood Pallets.

Service Environment Conditions:

Average Handling and Treatment, Medium-Duty Loads, Dry Environment (EMC <= 19%)

Predicted Service Life: 8 Cycles **Predicted Cycles until First Repair:** 3

Results from Handling Cycle Simulation

Pallet Components		Cycles To First Repair	Cycles To First Replacement	Number of Times Replaced	Limits Pallet Service Life	Relative Component Damage during Simulation
Top Leadboards	(2)	3	5	1	Yes	
Top InteriorBoards	(5)					
Bottom Leadboards	(2)	3	5	1		
Bottom InteriorBoards	(3)					
Exterior Stringers	(2)	4				
Interior Stringers	(1)					

Effect of Fastener Quality

Factors Affecting Durability

- F(1) - factor for fastener-withdrawal resistance

$$W = 1380 G^{2.5} D_s L_p C_w C_m K_F$$

W - Withdrawal resistance (lbf [N])

G - Specific gravity (oven-dry weight and volume basis or equivalent specific gravity)

D_s - Diameter of nominal shank (in. [mm])

L_p - Length of penetration into main member (in. [mm])

C_w - Fastener withdrawal adjustment (calculated or empirical)

C_m - Moisture adjustment factor

K_F - Strength level conversion factor (3.32)

Effect of Fastener Quality

Factors Affecting Durability

- F(1) - factor for fastener-withdrawal resistance

Thread Angle

$$C_w = 1 + K(D_t - D_s)(H/L_t)$$

Thread Press-out

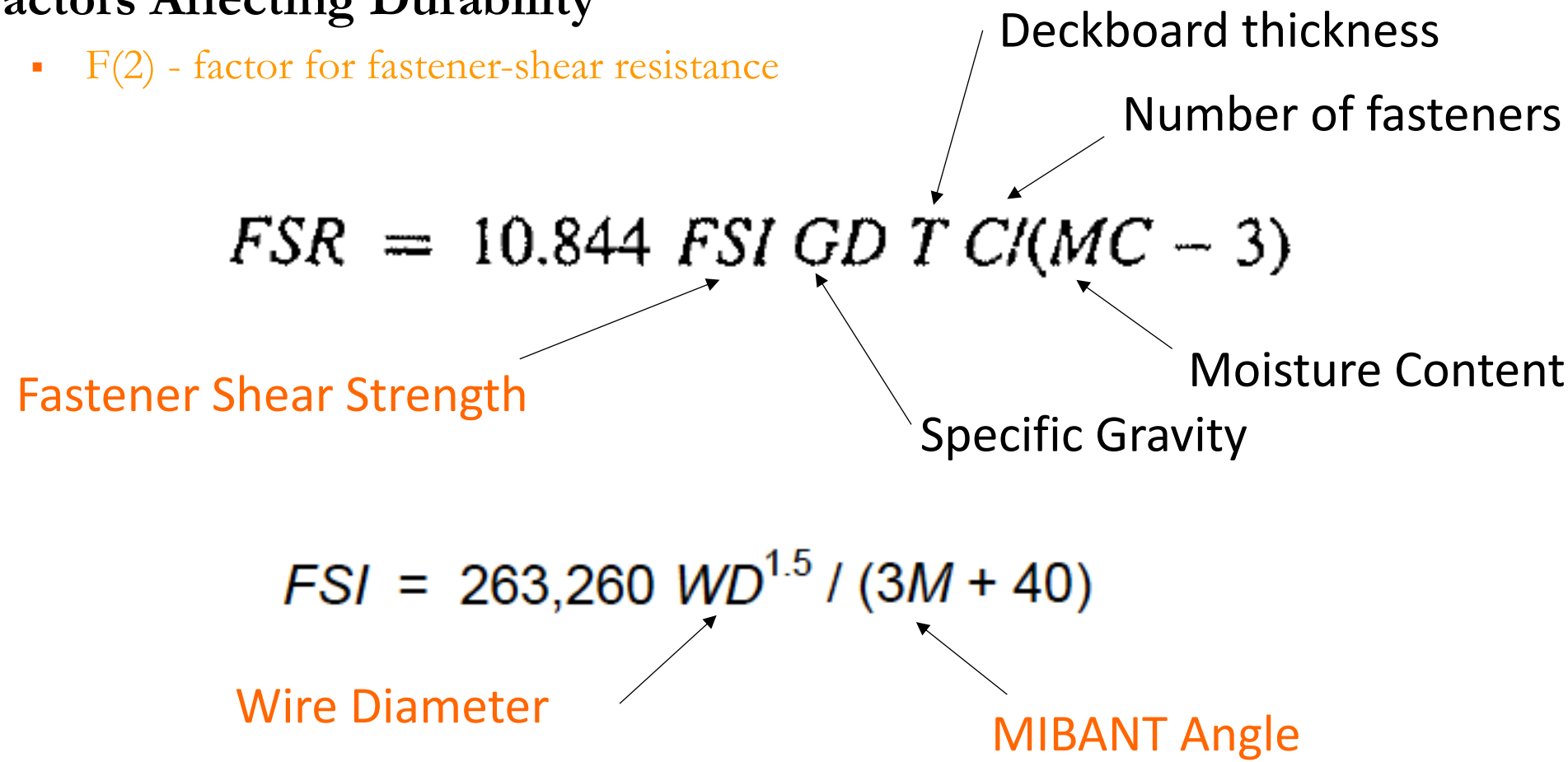
where

- C_w - Fastener withdrawal adjustment
- K - Constant (helically threaded = 22, annularly threaded = 60)
- D_t - Diameter of the thread crest (in. [mm])
- D_s - Diameter of the nominal shank (in. [mm])
- H - Number of helixes
- L_t - Thread length (in. [mm])

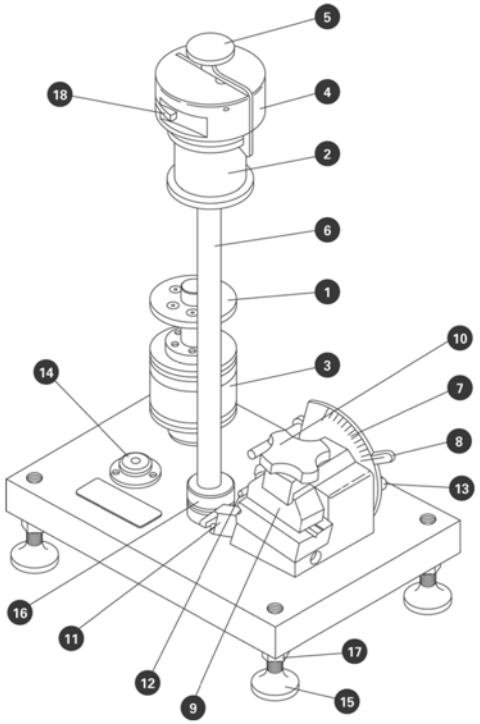
Effect of Fastener Quality

Factors Affecting Durability

- F(2) - factor for fastener-shear resistance



Measurement of Fastener Quality



MIBANT Test
(ASTM F680)

Bending Yield Strength Test
(ASTM F1575)

MIBANT Testing

Fastener Pull Through Testing

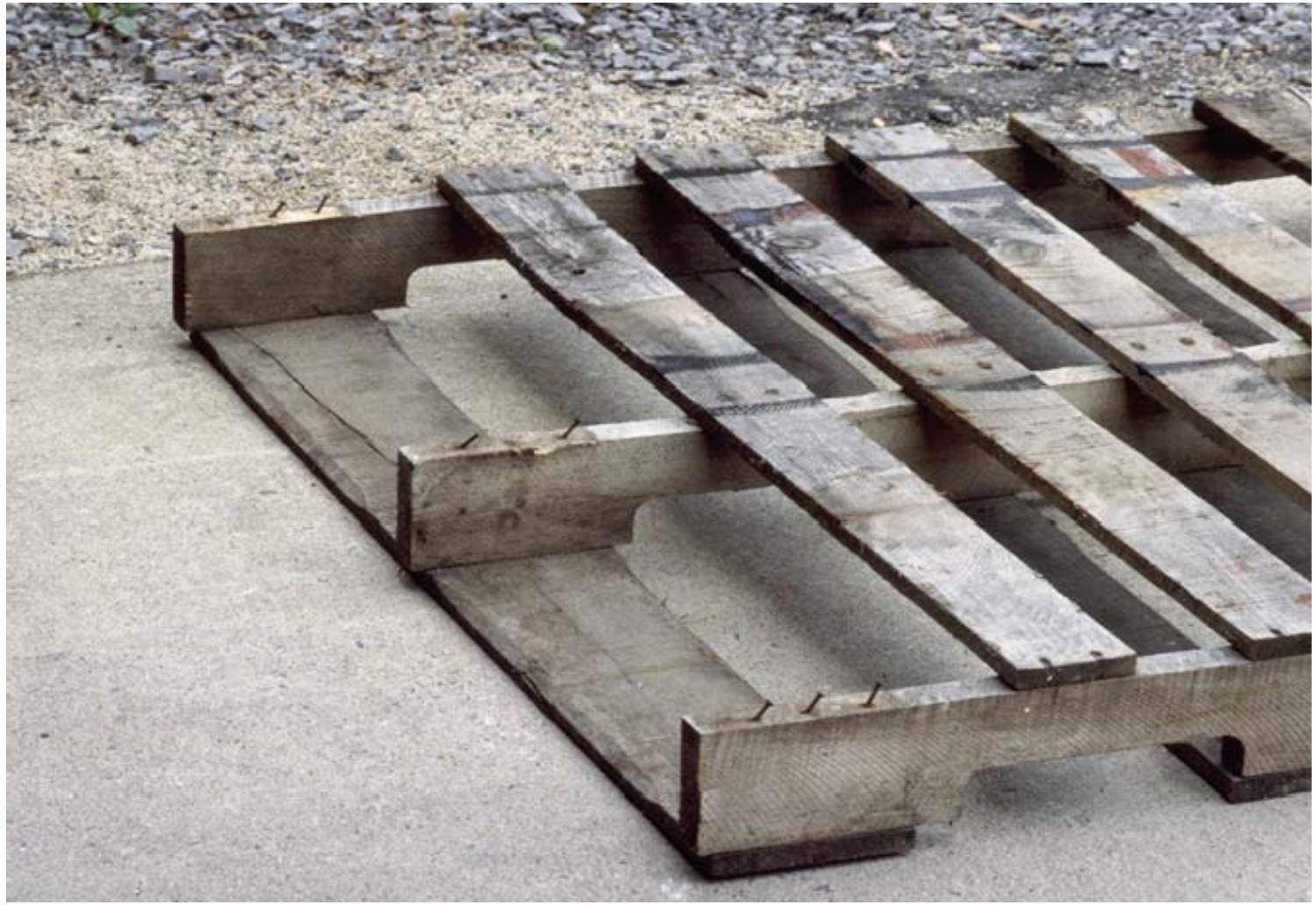
VIRGINIA TECH

Fastener Pull Through Testing

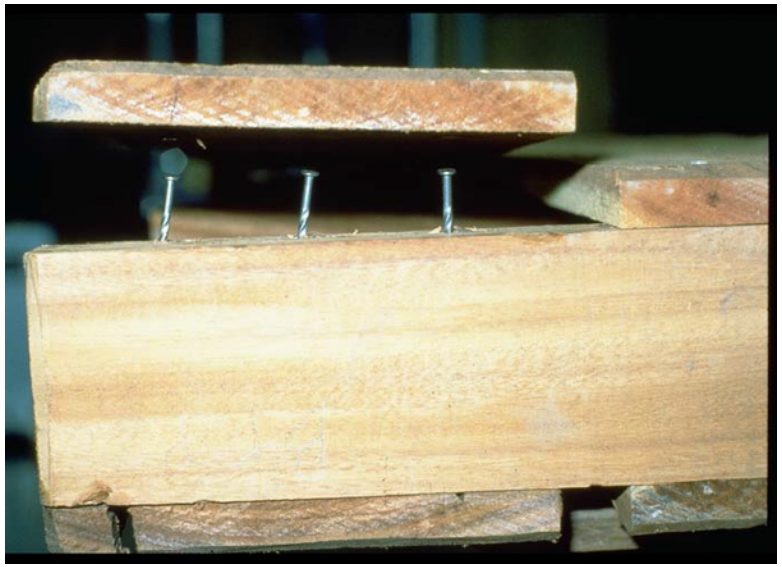
Effect of Fastener Quality

Pallet Connection Failure

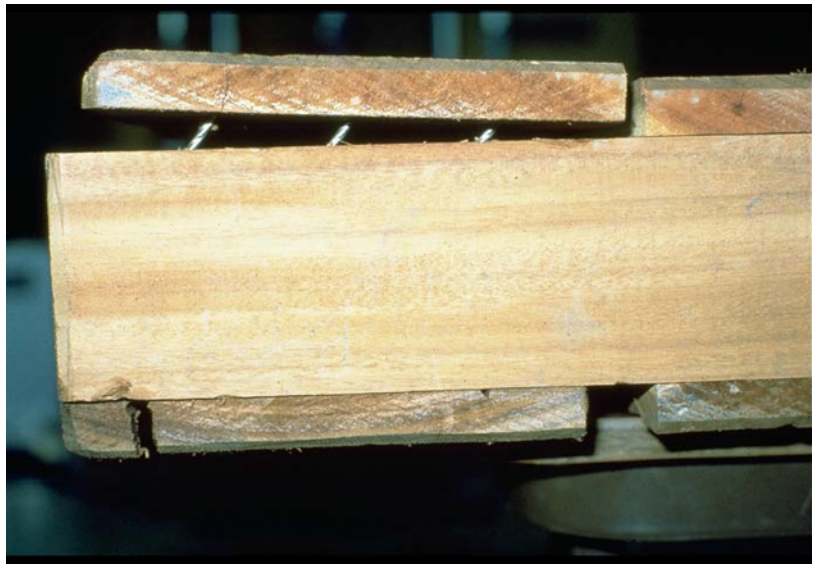
Pallet Connection Failure Modes



Pallet Connection Failure Modes



Head Pull Through

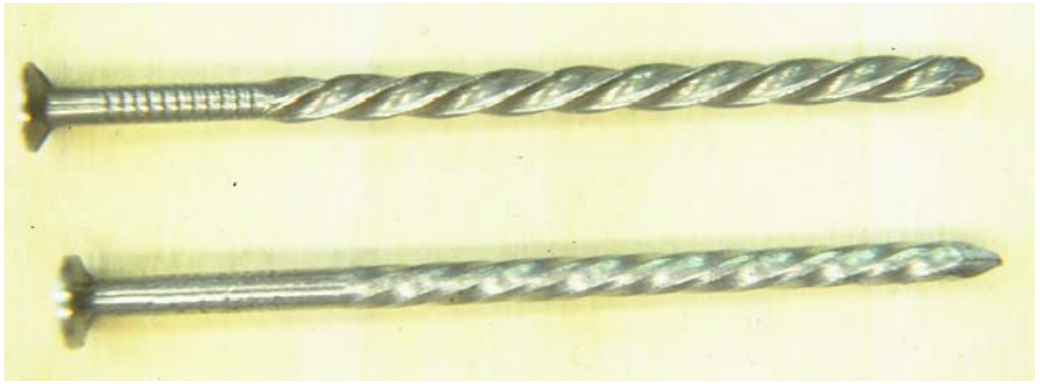


Shear

Shank Withdrawal

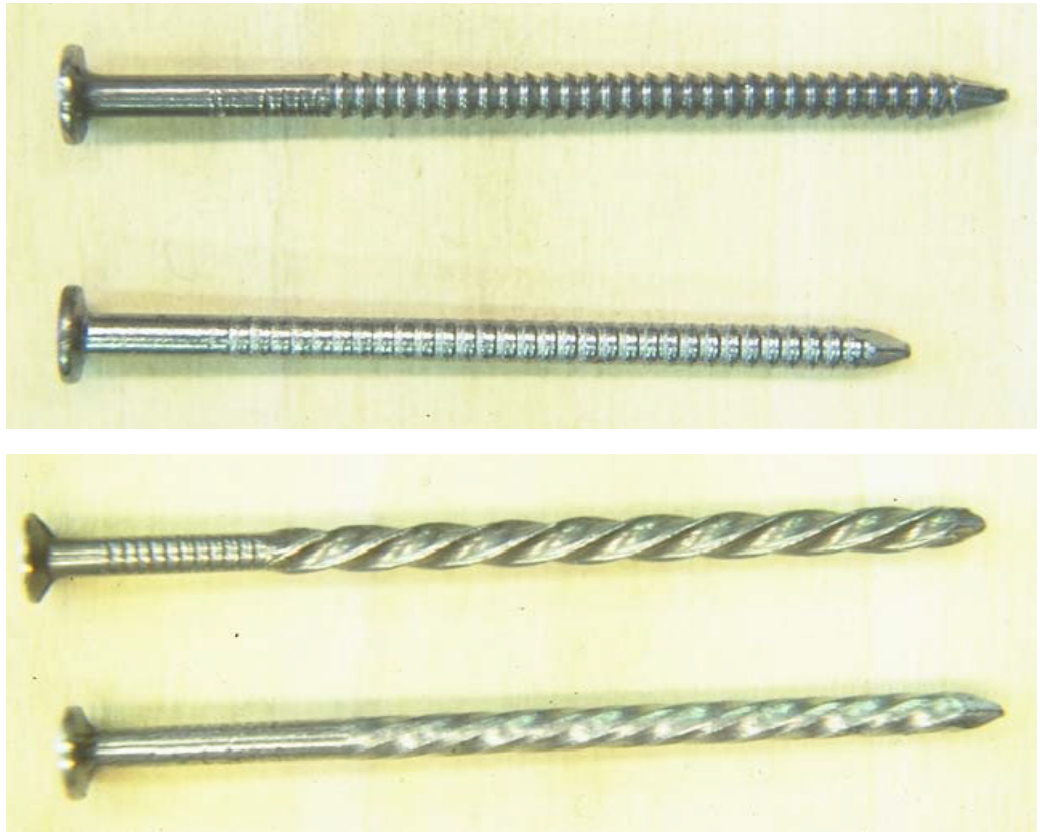
Effect of Fastener Quality

Press-Out



Thread Angle

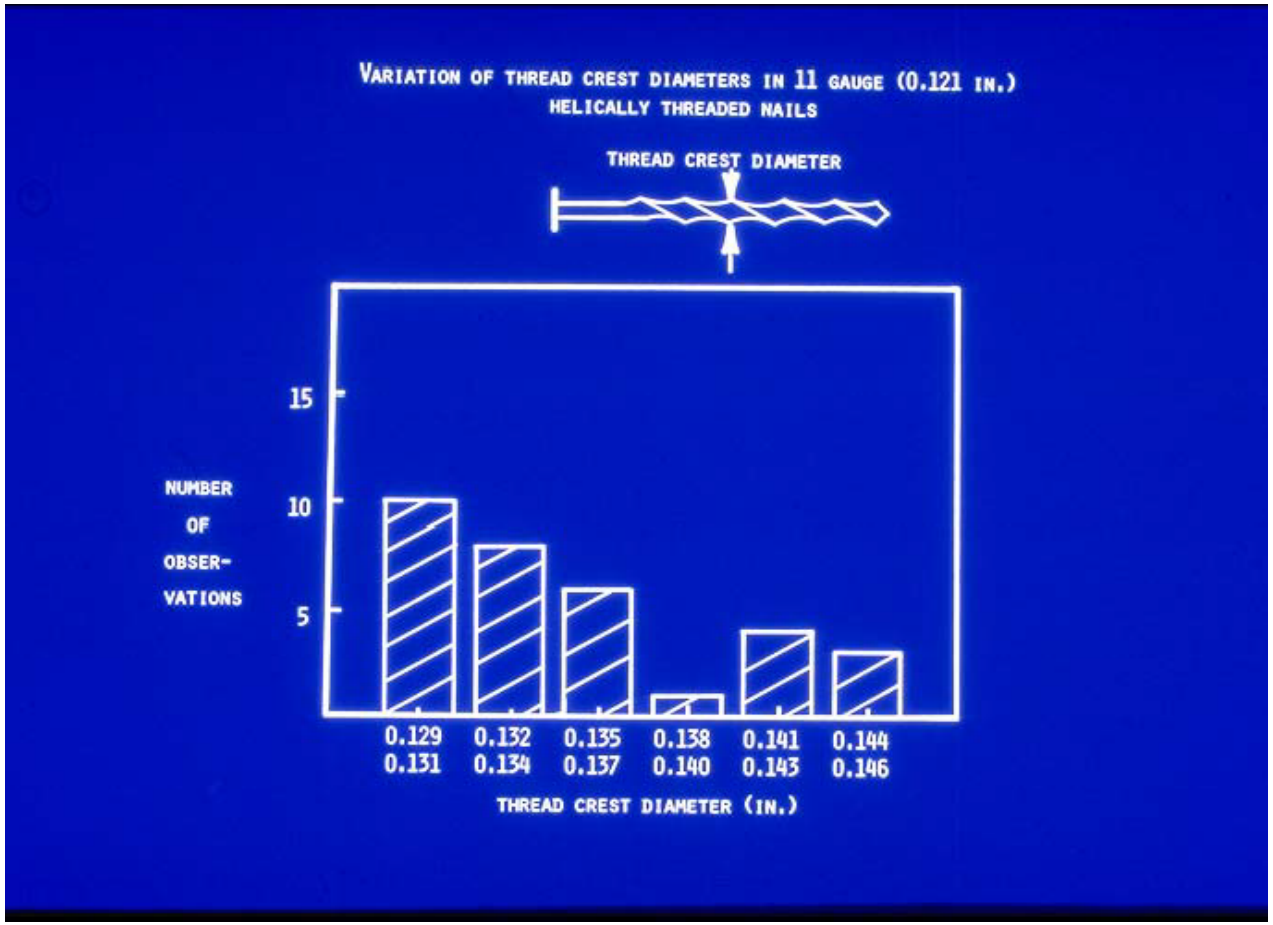
Effect of Fastener Quality



Press-Out

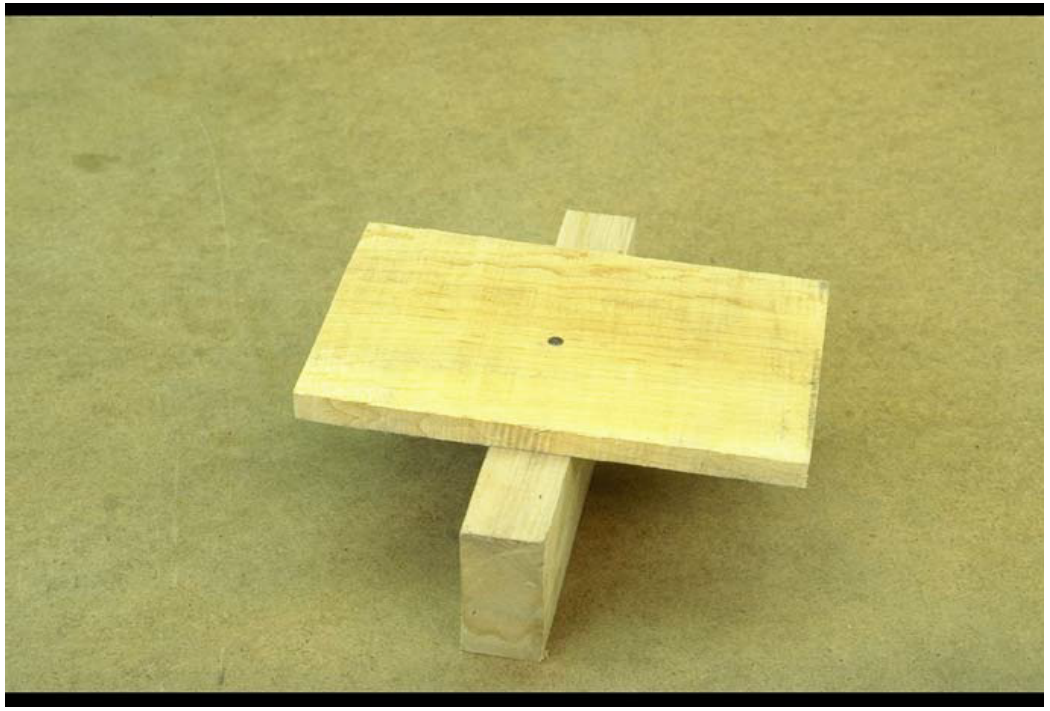
- Difference between the wire diameter and the thread-crest diameter
- Affects the withdrawal strength

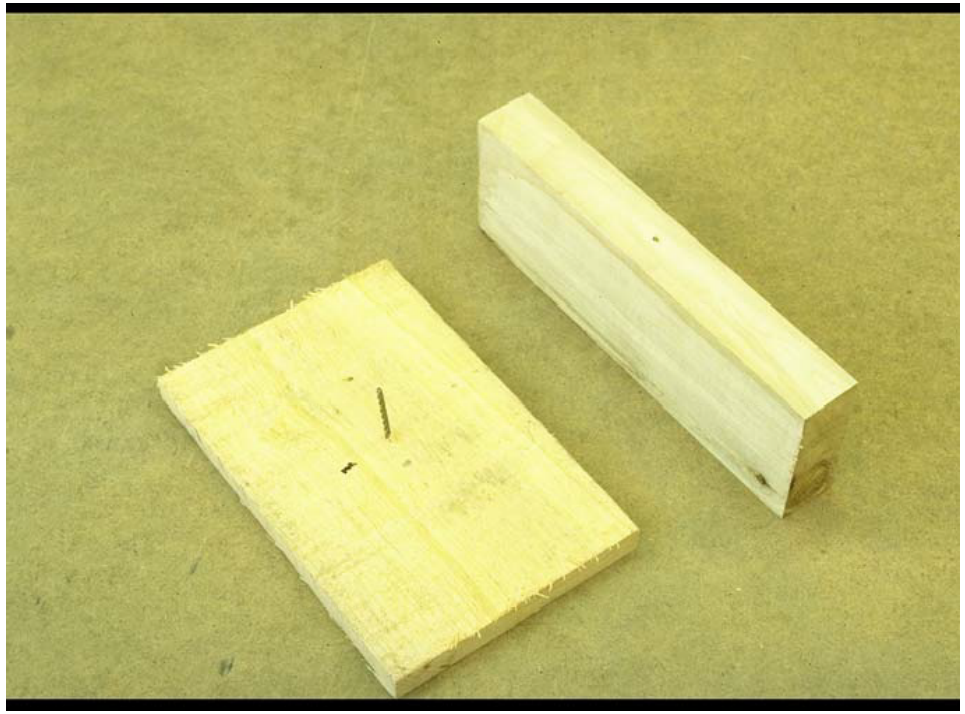
Effect of Thread Press-out



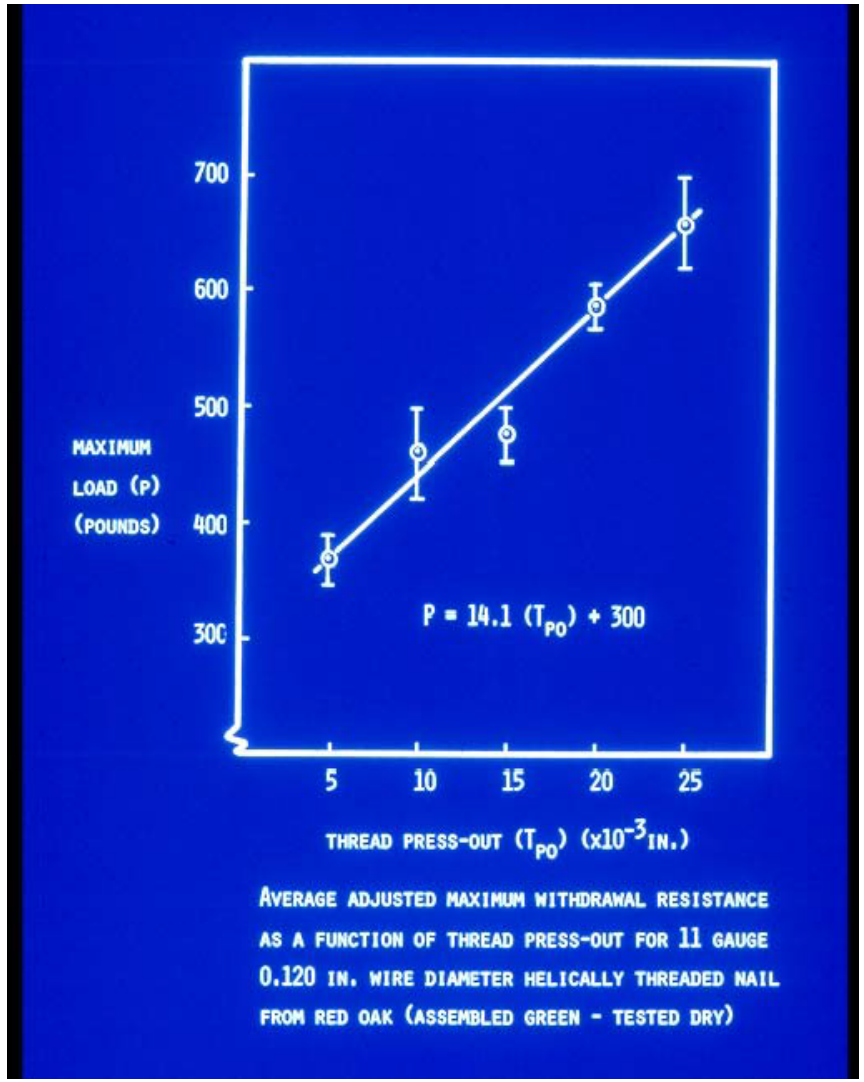
- 11 gauge (0.121 in.) helical nail was used
- Thread crest diameter was recorded for each nail
- Deckboard was secured to a stringer using one nails
- Green Red Oak was used
- Withdrawal test was conducted

Effect of Thread Press-out





Effect of Thread Press-out



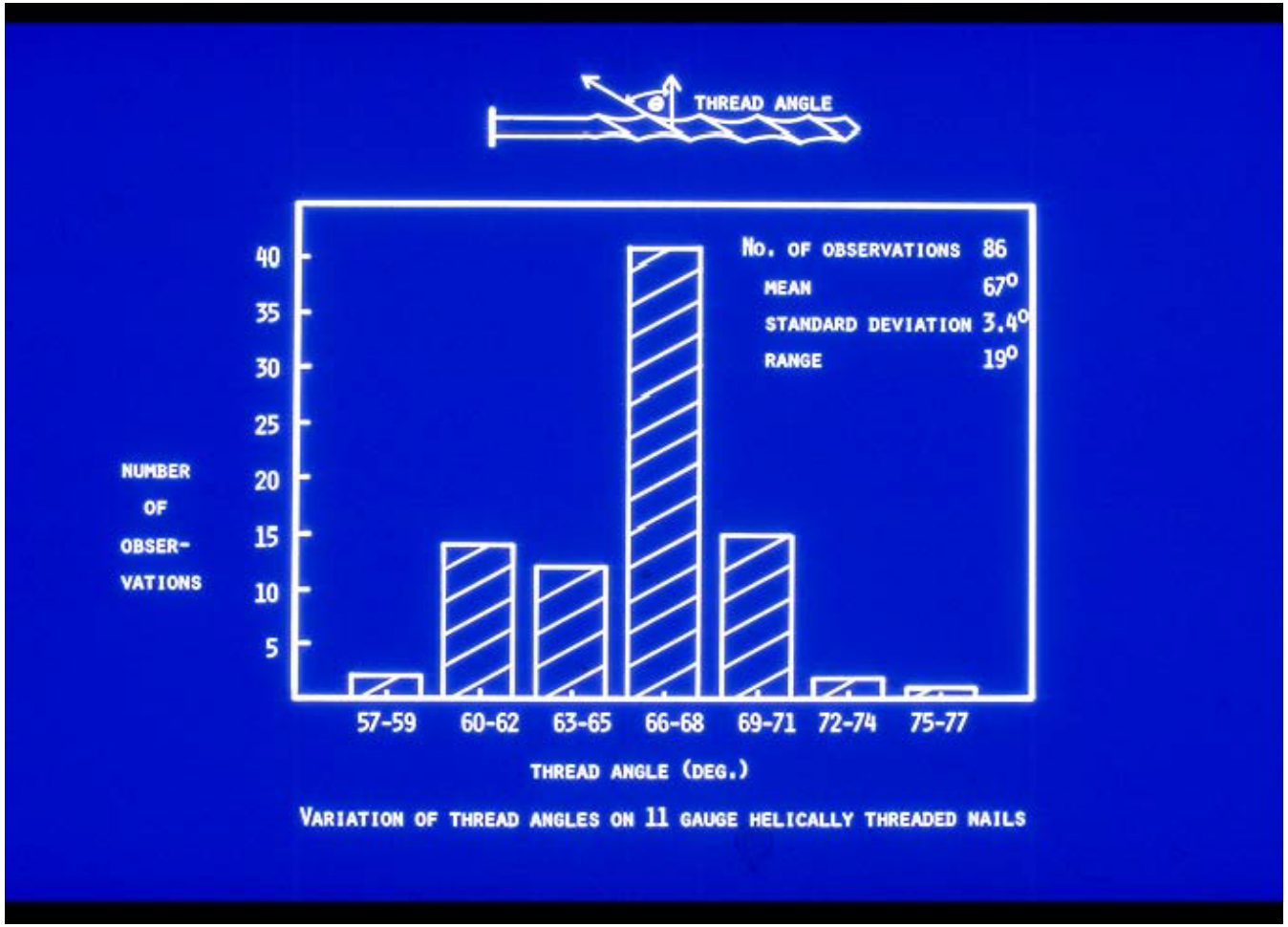
- Linear correlation was found between the amount of press-out and the withdrawal resistance
- Increasing the press-out by 0.015 in. increases the withdrawal resistance by 55%

Effect of Fastener Quality

Thread Angle

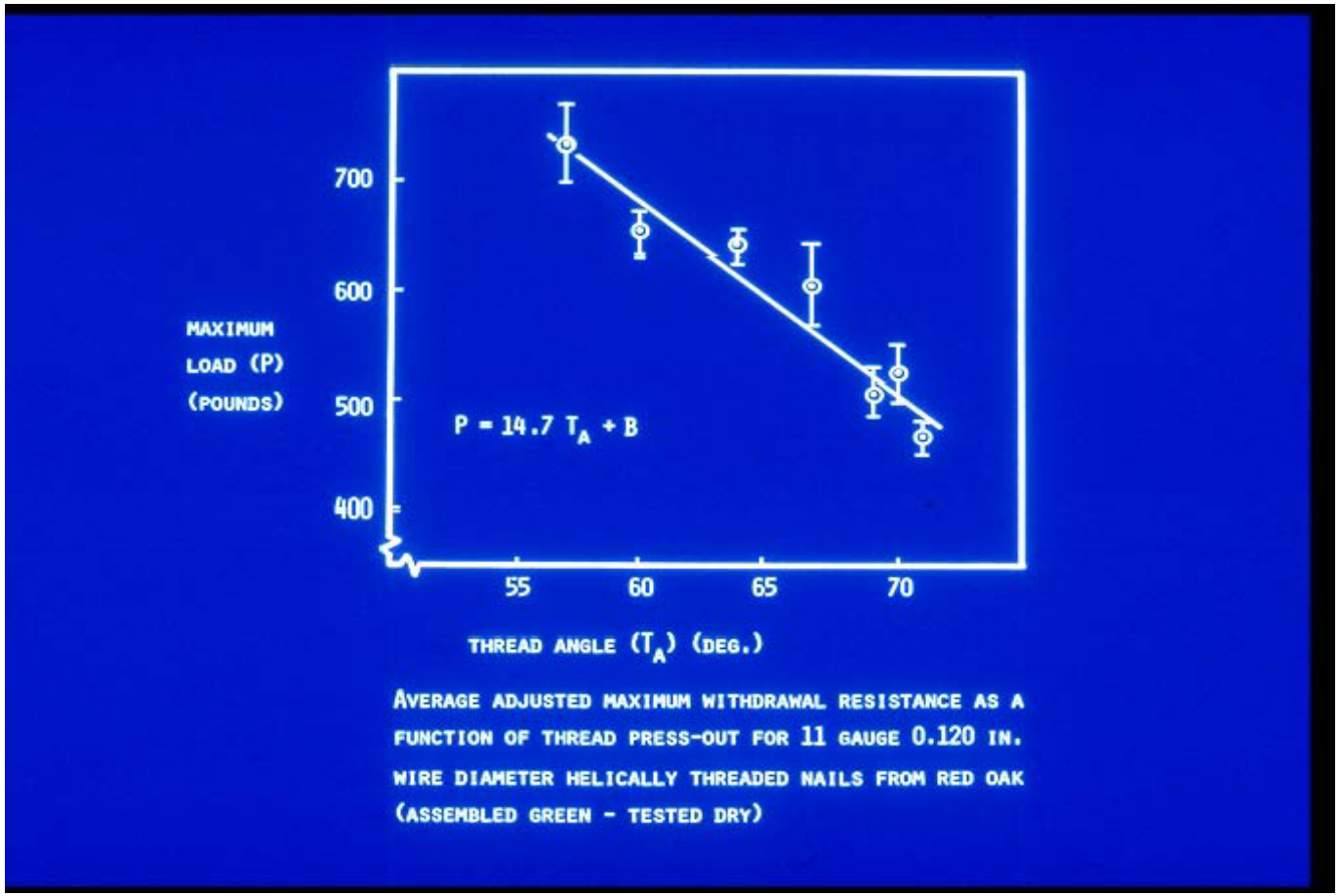
- Angle of the helixes
- Can be calculated from the number of helixes and the thread length
- Affects the withdrawal strength

Effect of Thread Angle



- 11 gauge (0.121 in.) helical nail was used
- Thread length was recorded for each nail
- Deckboard was secured to a stringer using one nails
- Green Red Oak was used
- Withdrawal test was conducted

Effect of Thread Angle



- Linear correlation was found between the thread length and the withdrawal resistance
- Decreasing the thread length from 68 to 60 degrees increases the withdrawal resistance by 34%
- Thread angle below 60 degrees is not recommended because it adversely affect fastener drivability

Fastener Application

Recommended Fastener Quality

- Recommendations are outlined in Uniform Standard for Wood Pallets (2014)

https://cdn.ymaws.com/www.palletcentral.com/resource/collection/E8AADDDE-7CBA-4298-8341-C7F29D0C14FF/Uniform-Standard-for-Wood-Pallets-2014(REV).pdf

Application		Nails						Staples
		Minimum Penetration	Minimum C_w[b]		Minimum C_z[c] and F_{yb}[d]		Minimum head-shank ratio		Minimum crown length
		in. (mm)	R	S	R	S	R	S	in. (mm)
Stringer or block pallets	New	1 in. (≤ 0.5 in. db)	1.9	1.5	$1.0 < Cz < 1.5$ and $F_{yb} > 100$ ksi (690 MPA)		2.25	2.00	0.375 (9.5)
	Repair	1.25 in. (> 0.5 in. db)	1.5				2.00		
Clinched mat	All	Complete penetration and clinched	1.0	1.0			2.00	2.00	0.375 (9.5)

Number of Fasteners per Connection

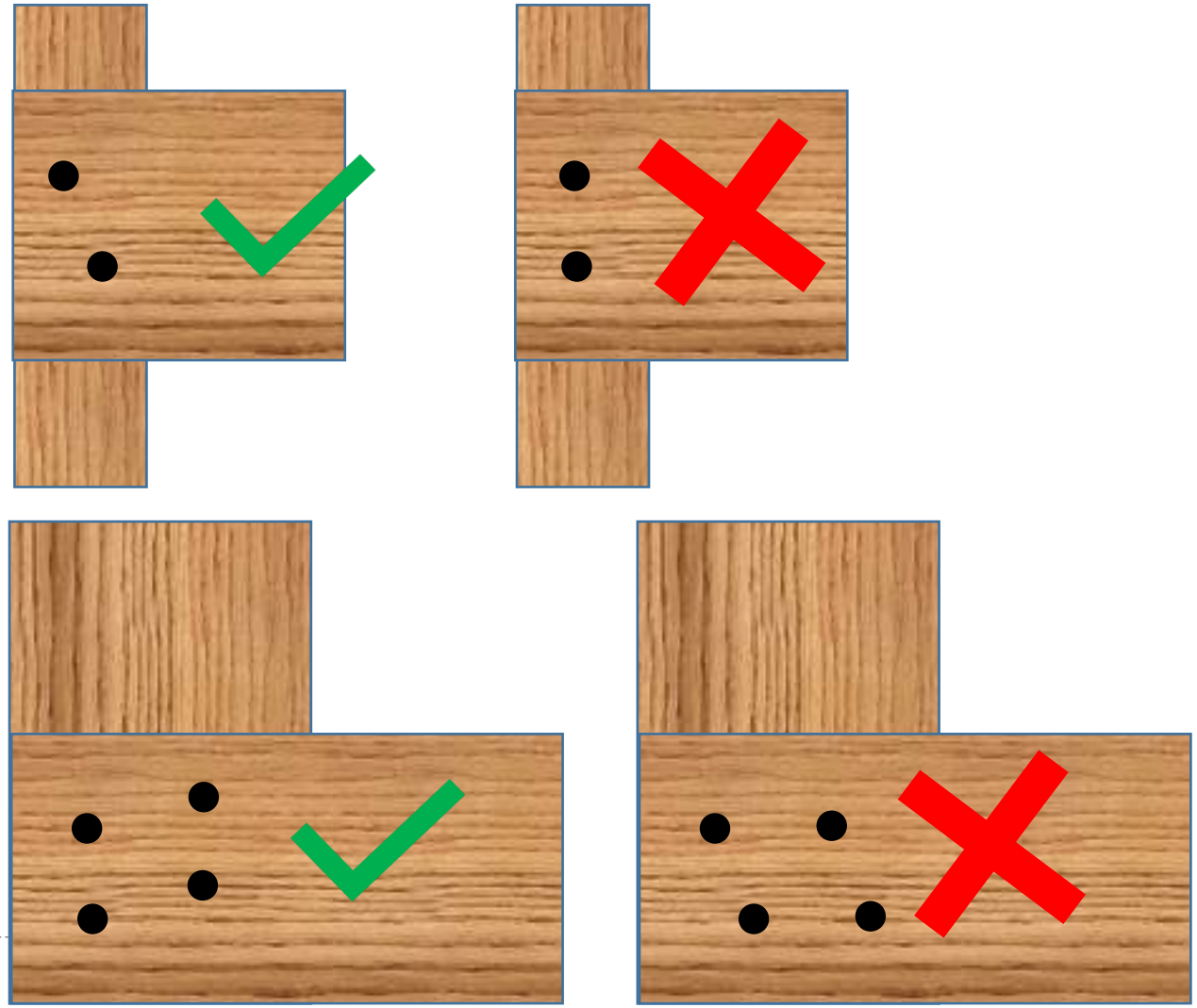
- Minimum recommended number of fasteners per connection

DECKBOARD WIDTH	MINIMUM NUMBER[a] OF FASTENERS PER CONNECTION OF SINGLE-USE OR REUSABLE PALLETS
Up to 5-1/4 in. (133 mm)	2
5-1/4 up to 7 in. (133-179 mm)	3
7 to 8 in. (179-203 mm)	4
Corner block	3[b]
Interior block	2

a no less than one nail or staple per 8 sq. in (5,161 mm^2) of block fastening surface

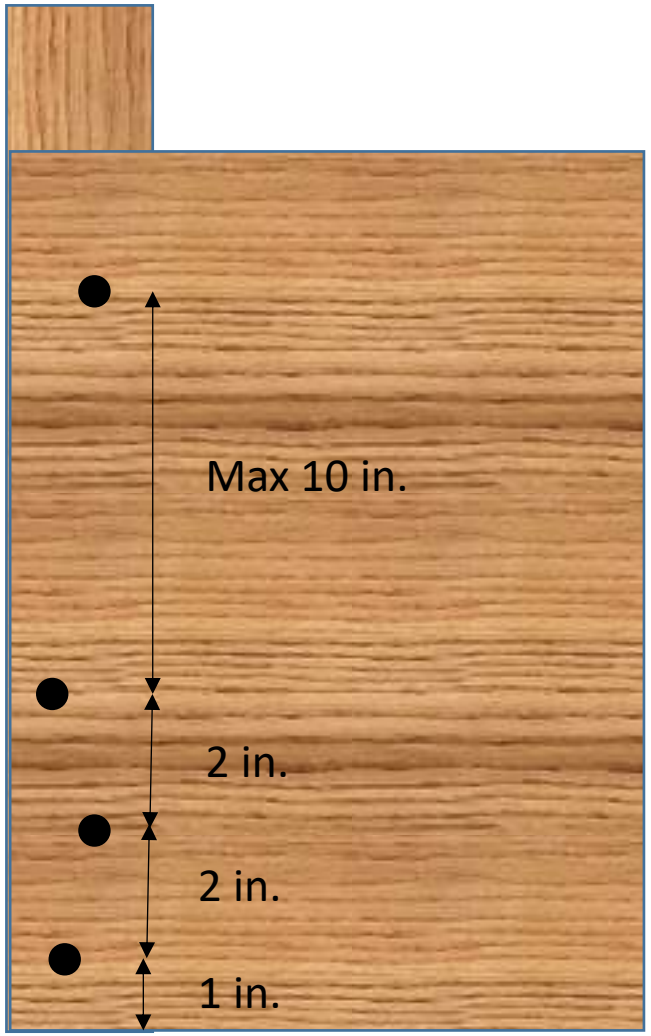
b corner blocks with less than 16 sq. in. (10,322 mm^2) of block fastening surface shall be connected with at least two (2) fasteners

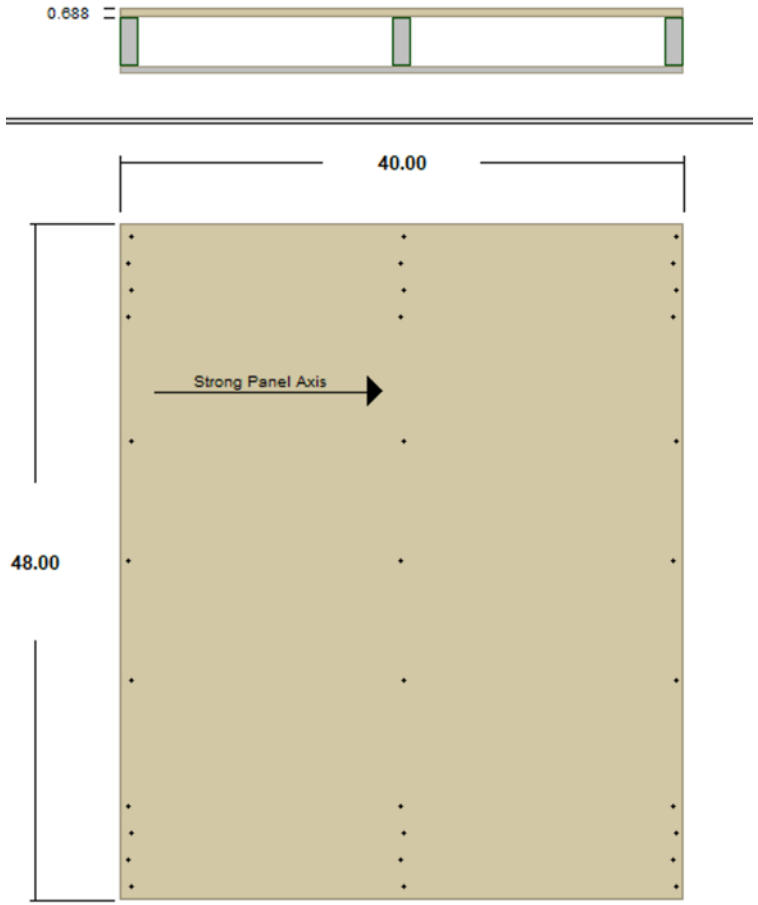
Fastener Placement



- Place fasteners to avoid splitting
- Do not align fasteners along the grain → stagger fasteners
- For block pallets, stagger fasteners to avoid splits in top deck and not block
- PDS does not let you stagger 4 block fasteners

Fastener Placement





- Panel deck stringer pallets
  - Min. 3 fasteners at the end
    - 1 in. from end
    - 2 in. center to center offset for next two
    - Max 10 in. offset for all interior fasteners
  - PDS requires min. 4 at panel ends

Fastener Pop-up

- No fasteners can protrude in exposed surfaces → product damage
- Two protruding fasteners are allowed on unexposed surfaces as long as they do not affect pallet performance
- Protruding fasteners are not permitted for clinched fasteners
- Counter sinking fastener heads do not significantly affect pallet performance

Bolts

- Bolt type: Class 1A (ASME B1.1)
- Bolt holes need to be larger than the bolt diameter
  - 1/32 in. larger for bolts < 0.5 in. diam.
  - 1/16 in. larger for bolts > 0.5 in. diam.
- Green pallets the holes need to be twice as large to accommodate shrinking
- Use multiple bolts to prevent block rotation
- Washers are recommended
- Should not be used in conjunction with nails

Lag Screws

- Lag Screw needs to be in compliance with ASME B18.2.1 and B18.6.1
- Over driving should be avoided
- Minimum penetration should be 2/3 of screw length and 7x the shank diameter
- Pre-drill diameter should not be more than the shank diameter
- Washers are recommended

Conclusion

- Fasteners have a significant effect of pallet durability
- Fasteners are only 5% of the pallet cost
- Most important fastener parameters:
  - MIBANT or Bending Yield Strength
  - Wire Diameter
  - Thread Angle
  - Thread Press-Out

Only use good quality fasteners!!!!

Thank you for your attention

LASZLO HORVATH, PHD, CPLP

ASSOCIATE PROFESSOR
DIRECTOR, CENTER FOR PACKAGING AND UNIT LOAD DESIGN

DEPARTMENT OF SUSTAINABLE BIOMATERIALS
VIRGINIA TECH

VIRGINIA TECH

VIRGINIA TECH