NAILS: Let’s Get to the Point

By Rick Allen

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Nails are an integral part of modern wood frame construction structural connections such as framing, floors, walls, and roofs. These are the building blocks needed for a structure prior to completing a proper building envelope. For many, important information regarding nails and their use may need refreshing and updating.

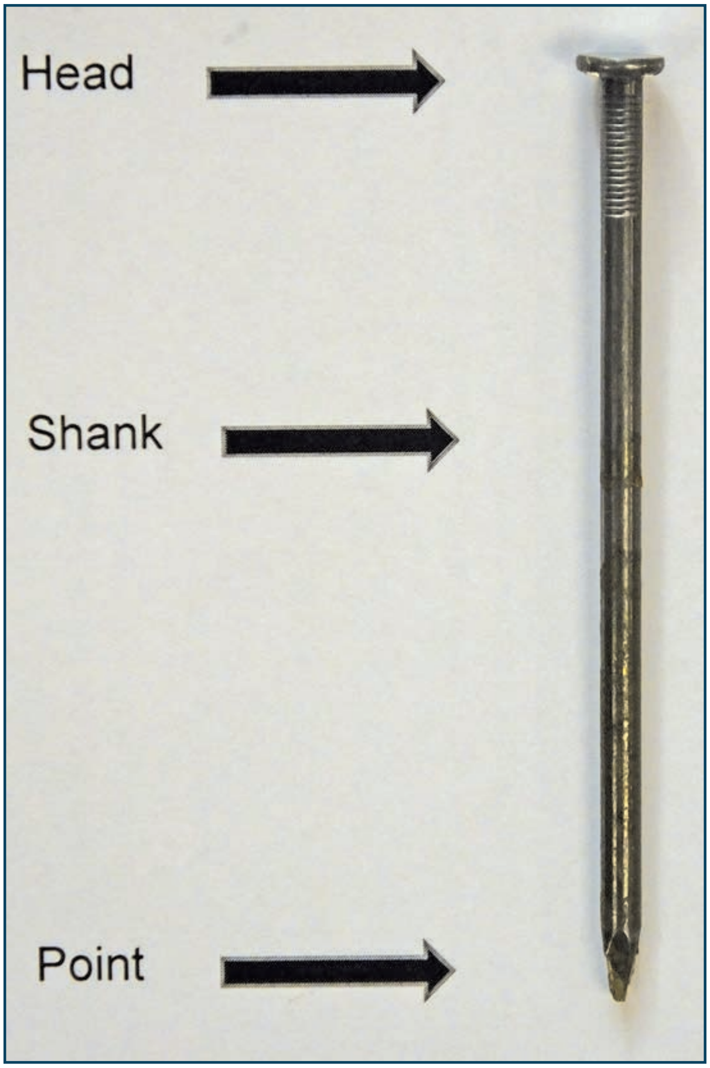


Figure 1 – Physical features of a nail.

WHAT IS A NAIL?

By definition a nail is:

- A straight, slender fastener
- Usually pointed and headed
- Typically 6 inches or fewer in length
- Designed to be driven
- Designed to hold two or more pieces together or to act as support

Most nails made today are formed from wire and have three physical features: the head, the shank, and the point (*Figure 1*).

ASTM International standard F1667, *Standard Specification for Driven Fasteners: Nails, Spikes and Staples*, provides information on materials of fabrication, dimensions and tolerances, coatings, style, strength requirements, and other information.

The American Wood Council (AWC) publications—*National*

IBC	IBC	IRC
Fastening Schedule	2014.10.1	R602.3(1)
Hardboard Siding	2308.6.3(5)	R602.3(2)
Underlayment Application	1507.1.1(2) & 1507.1.1(3)	R905.1.1(2)
Wood Shingle and Shake	1507.8	R905.7.5(2)

Table 1 – There are multiple tables in the IBC and the IRC that provide prescriptive fastening requirements. Some are included here.

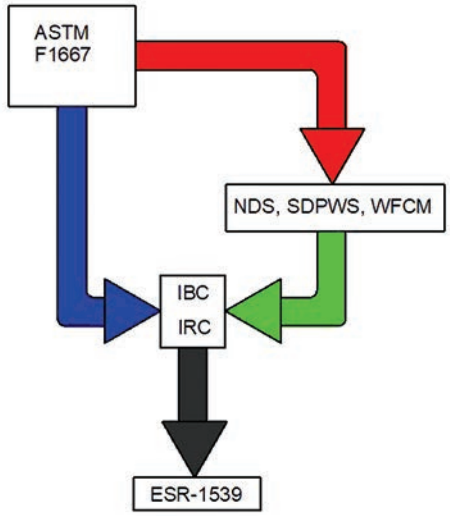


Figure 2 – Relationship between ASTM F1667, AWC Standards, the I-Codes and ESR-1539

Design Specification® *for Wood Construction (NDS*®*), Wood Frame Construction Manual (WFCM),* and *Special Design Provisions for Wind & Seismic (SDPWS)*—incorporate specific information regarding nails for designers and subsequently are referenced in sections of the building codes. These AWC documents provide information on design values for nails regarding:

- Reference nail withdrawal values
- Reference lateral design values
- Reference nail head pull-through values
- Design requirements
- Shear capacities

There are two primary methods for the development of building designs: prescriptive and performance.

ASTM F1667 and the AWC documents tie into the International Building Code (IBC®) and International Residential Code (IRC®). There are multiple tables in the IBC and the IRC that provide prescriptive fastening requirements. These tables include but are not limited to those listed in *Table 1*.

Designers have alternatives to the prescriptive requirements called out in the codes as well. These alternatives, "performance," may be developed by using the design information provided in the AWC documents in conjunction with competent engineering design, accurate fabrication, proper supervision of construction, and use of recognized alternative materials such as those listed in code evaluation reports (*Figure 2*).

One of the most prominent code evaluation reports for nails is the ICC Evaluation Services report ESR-1539 http://www.icc-es.org/reports/pdf_files/ESR-1539.pdf, of which ISANTA is the report holder.

WHAT CHARACTERISTICS MUST A DESIGNER OR BUILDER BE CONCERNED WITH?

Whether a designer uses prescriptive requirements or independent design, there are a number of engineering aspects that must be considered when specifying the proper nails for the applications.

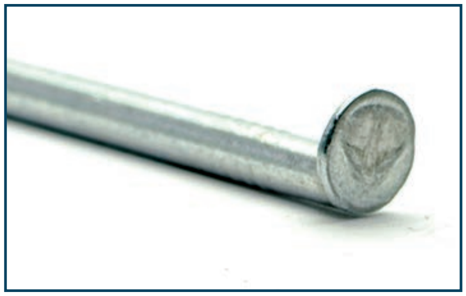
Nail sizes are typically described with reference to dimensions and style. Dimensionally, references are made to length, nominal shank diameter, and, where necessary, head diameters.

> **Example:** 2½ x 0.131 in., where 2½ in. is the length of the shank and 0.131 in. is the nominal shank diameter.

Often described in terms taken from ASTM F1667, common nails, box nails, and cooler nails are referenced in the prescriptive requirements of the IRC and IBC. Although common, box, and cooler nails are similar in shape, they differ dimensionally. *Table 2* shows the most frequently referenced sizes of these nail types. ASTM F1667 also references these nails with terms such as 6d, 8d, 10d, 12d, etc.

	Table 6 Type I, Style 4A Box Nails	Table 10 Type I, Style 7 Cooler Nails	Table 15 Type I, Style 10 Common Nails
	L x D - head diameter	L x D - head diameter	L x D - head diameter
6d	2 x 0.099 - 0.266	1⅞ x 0.092 - 0.250	2 x 0.113 - 0.266
8d	2½ x 0.113 - 0.297	2⅜ x 0.113 - 0.281	2½ x 0.131 - 0.281
10d	3 x 0.128 - 0.312	2⅞ x 0.120 - 0.297	3 x 0.148 - 0.312
12d	3¼ x 0.128 - 0.312	================	3¼ x 0.148 - 0.312

Table 2 – Nail comparisons by designation.



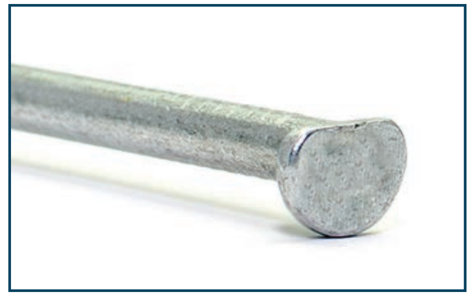


Figure 3 – Head configurations for power tool-driven nails, left to right: full round, offset round, and D-head. Photos courtesy of Falcon Fasteners.

Note that a 6d box ≠ 6d cooler ≠ 6d common nail. This applies to other sizes and other styles where the "d" designation is referenced. Always verify that the dimensions of the nail are referenced and the proper-size nail for the application is being used.

HEAD DIMENSION AND CONFIGURATION

Nails listed in ASTM F1667 are, with a few exceptions, full, round, and concentric to the shank. Tolerances are provided for hand-driven nails. There are provisions that allow nails manufactured for use in power-fastening tools to have other head shapes (D-head, offset round, etc.) and to be manufactured to the tolerances specified by the manufacturer. See *Figure 3*.

SHANK STYLES

Nails are typically referenced as smooth-shank or deformed-shank (ring and screw). See *Figure 4*.

For the various types of nails referenced in ASTM F1667, dimensions and tolerances are addressed as follows:

Nail Lengths

- Lengths for typical flat-head nails are measured from the bottom side of the head to the tip of the point.
- Length tolerances vary based on the overall length of the nail.
- The minimum length of the ring shank portion of a nail is defined only for Roof Sheathing Ring Shank (RSRS) and Post Frame Ring Shank nails (PFRS).

Nail Diameters

- Shank diameters and tolerances are based on smooth-shank nails or the smooth portion of a deformed shank nail.
- Diameters for the ring (deformed) portion of ring shank nails are defined for only the RSRS and PFRS nails. All other deformed shank dimensions are at the discretion of the manufacturer.

MATERIAL AND COATINGS

Most nails used in construction are made of carbon steel and, to a lesser extent, stainless steel. Carbon-steel nails are made of low-carbon, medium-low carbon, or medium-high carbon steel. Stainless steel nails are made of 302, 304, 305, or 316 stainless, with the most commonly used grades being 304 and 316. Other materials, such as copper, aluminum, or brass are called out for specialized applications.

The codes specify that nails used in preservative-treated wood, fire-retardant wood, and a variety of roofing materials (asphalt shingles, durable wood shingles, tile, etc.) have specific requirements with regard to corrosion resistance. Hot-dip galvanization per ASTM A153 (*Standard Specification for Zinc Coating [Hot Dip] on Iron and Steel Hardware*) Class D (1oz./ft^2) coverage or stainless steel is referenced in a number of locations in the codes.

In addition to the code requirements, a designer needs to consider other applications and environmental factors when determining the proper material and coating compatibility needs in a design. Factors such as outdoor exposure to moisture or salt spray or attachment with dissimilar metals may compromise a fastener without the proper corrosion protection.

MECHANICAL PROPERTIES

Three mechanical properties of nails are called out in ASTM F1667: ductility, tensile strength, and bending yield strength.

- Nails shall be sufficiently ductile to withstand cold bending without fracture. This applies only to unhardened nails.
- Tensile strength is the measurement of force required to pull the wire used in making the nail to the breaking point.
- Bending yield strength (F_{yb}) is the resisting strength of the nail to permanent yield when subjected to a lateral or side load. Yield is the point where an elastic material (in this case, steel) will not have the ability to return to its original state and will consequently be permanently deformed.

Of these three properties, the most critical for the designer is the bending yield strength.

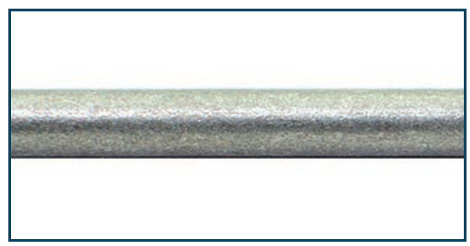


Figure 4 – Typical nail shank configurations. Top to bottom: smooth-shank, ring-shank, and screw-shank. Photos courtesy of Falcon Fasteners.

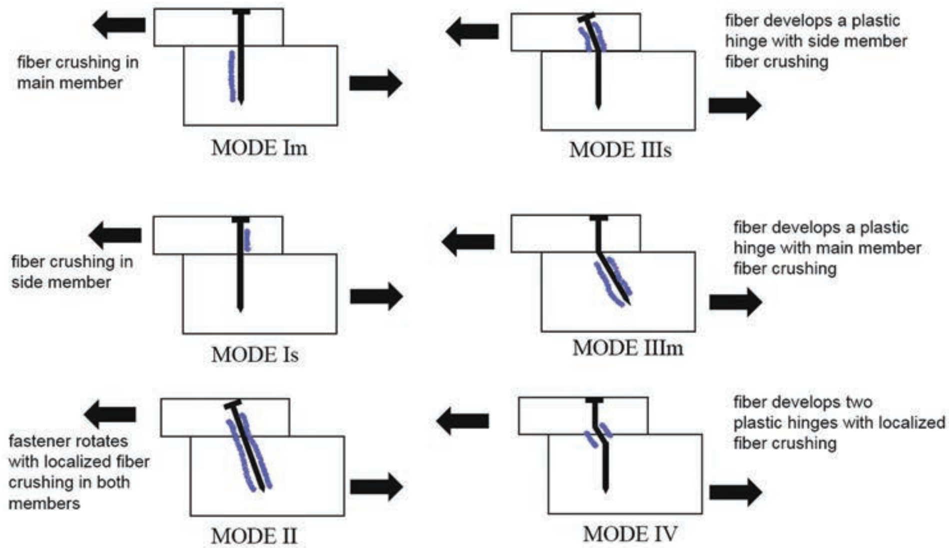


Figure 5 – Connection yield modes.

INFORMATION AVAILABLE FOR THE DESIGNER

Bending Yield Strength (F_{yb}):

Within ASTM F1667 and the NDS, there are provisions for minimum F_{yb} requirements for nail shank diameters (D):

- 100,000 psi for nails 0.099 ≤ D ≤ 0.142 inches in diameter
- 90,000 psi for nails 0.142 < D ≤ 0.177 inches in diameter

These minimum requirements cover most of the nail diameters used in wood-frame construction.

Reference Lateral Design Values

The bending yield strength of the nail is used in determining the mode of failure in a connection when subjected to lateral loads due to wind or seismic loading. There are six primary modes of failure in a single shear connection. These are depicted in *Figure 5* and are referenced in Appendix I of the NDS and in ESR-1539's Appendix A.

Additionally, equations used to calculate the reference lateral design values for each mode of failure are available in Section 12.3 of the NDS and in Appendix A of ESR-1539. These equations take into consideration nail diameter, nail-bending yield strength, the dowel-bearing strength of both the side member and the main member (a function of wood specific gravity), and length of the nail in both the side member and main member.

WITHDRAWAL CAPACITY

Nail withdrawal capacity (lb./in.) is the ability of a nail to resist withdrawal when driven into wood or wood products. The capacity is a function of the nail size, shank configuration, material of construction, and wood's specific gravity. In a connection, the withdrawal is based on the penetration of the nail into the main member, not the top or side member. The main member is considered to be the member that holds the point of the nail when driven (*Figure 6*).

In the 2018 NDS, significant changes were made with regard to nail withdrawal. These changes consist of the following:

- Establishment of tabulated withdrawal values for Roof Sheathing Ring Shank (RSRS) nails
- Reduction in withdrawal values of carbon steel (bright or galvanized) deformed shank nails (exception for RSRS and PFRS nails)

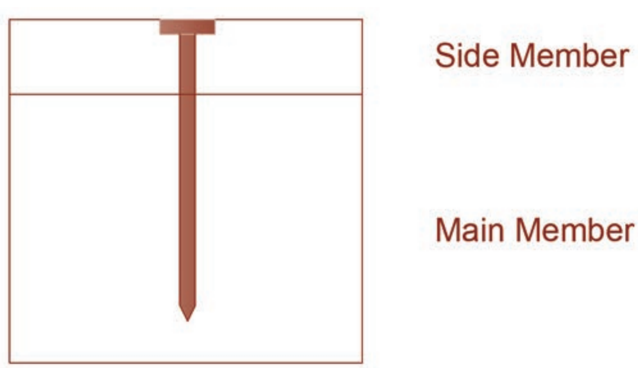


Figure 6 – Connection configuration.

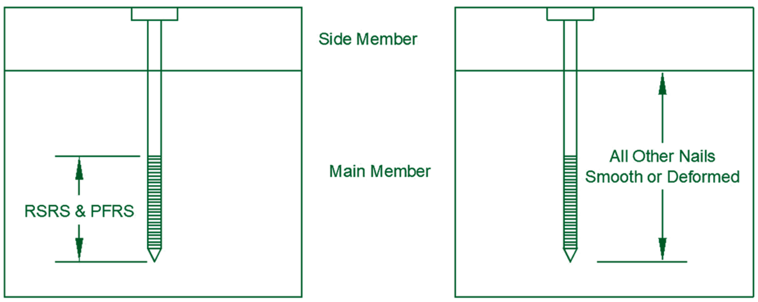


Figure 7 – Nail penetration basis for determining withdrawal.

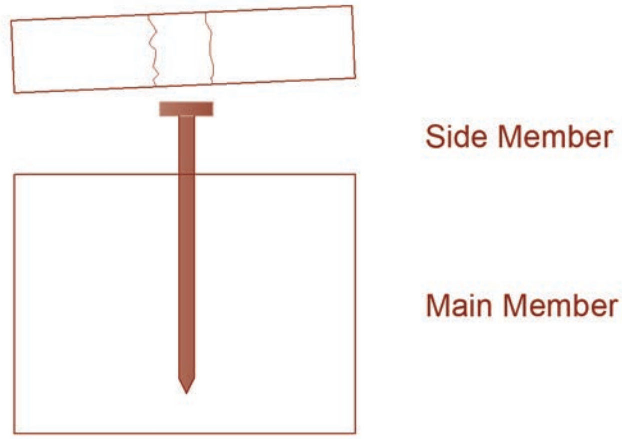


Figure 8 – Connection failure from pull-through.

- — Prior to the 2018 NDS, deformed shank nails were tabulated with an approximately 10% higher withdrawal capacity over a smooth-shank nail of the same diameter.
- Establishment of tabulated withdrawal values for stainless steel nails. Stainless steel nails—both smooth and deformed-shank—have significantly lower withdrawal values than carbon steel nails of the same size.
  - — Previously, stainless steel nails were tabulated with the same withdrawal values as carbon steel nails.

Withdrawal values for RSRS and PFRS nails are based on the length of ring penetration of the nail into the main members. Withdrawal values for all other nails are based on the total length of the nail penetration into the main member (*Figure 7*).

For more information on withdrawal values and changes to the NDS, please see https://tinyurl.com/yd3xaqwv.

NAIL HEAD PULL-THROUGH

Nail head pull-through is when the uplift forces on the side member in a nailed connection exceed the capacity of the member to remain in place, thus causing the nail head to pull through, separating members in the connection. In this case, the nail will remain driven into the main member of the connection (*Figure 8*).

With the publication of the 2018 NDS, pull-through values for round-head nails have been developed. Pull-through in a nailed connection is based on the side member thickness, side member specific gravity, and nail head perimeter. Tabulated values are available in NDS Table 12.2F, Head Pull-Through, WH, along with provisions on how to calculate pull-through values.

A partial list of the values for nonstructural 1 or marine-grade plywood is shown in *Table 3*.

When published in mid-2018, the "NDS With Commentary" will address pull-through for other head shapes, allowing a designer to calculate pull-through for these other head shapes.

With the addition of the nail pull-through values, the 2018 WFCM Table 3.10, "Roof Sheathing Attachments Requirements for Wind Loads," now addresses fastener uplift capacity for roof sheathing. These values are based on the minimum values obtained from nail withdrawal or head pull-through calculations.

SUMMARY

In a building design, there are a number of factors to take into consideration when using nails. These include but are not limited to nail size, nail materials of construction, corrosion protection requirements, and the types of materials the nail is driven into.

Nail size has a direct effect on the shear, withdrawal, and pull-through capacity in a connection. The material used to make a nail also determines the strength of the connection in terms of the ability to withstand shear loads, along with withdrawal and pull-through. Materials and coatings are also important factors in determining the levels

Side Member Specific Gravity	Head Diameter (in.)	Net Side Member Thickness (in.)											
		5/16	3/8	7/16	15/32	½	19/32	5/8	23/32	¾	1	11/8	1½
0.42	0.234	28	34	39	42	45	52	52	52	52	52	52	52
	0.250	30	36	42	45	48	57	60	60	60	60	60	60
	0.266	32	38	44	48	51	60	64	68	68	68	68	68
	0.281	34	40	47	50	54	64	67	75	75	75	75	75
	0.297	35	43	50	53	57	67	71	82	84	84	84	84
	0.312	37	45	52	56	60	71	75	86	89	93	93	93
	0.344	41	49	58	62	66	78	82	95	99	113	113	113
	0.375	45	54	63	67	72	85	90	103	108	134	134	134

Table 3 – Head pull-through values (pounds).

of corrosion protection required in the codes or under various environmental conditions.

With various references available—from published standards to evaluation reports—designers have multiple resources at hand to help in the design process, thus ensuring safe and reliable designs.

REFERENCES

American Wood Council. *National Design Specification for Wood Construction, 2018 Edition.*

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International Code Council. International Residential Code® for One- and Two-Family Dwellings (IRC®) and International Building Code® (IBC®). Washington, D.C.

ICC Evaluation Services. ESR-1539, Brea, CA.


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