Concrete fastener selection

Selecting the right nail for concrete

What determines nail performance

Hilti Direct Fastening systems are designed to achieve maximum performance in a wide range of applications. But there is a large variety of nails types and elements for various direct fastening concrete applications. To select the appropriate nail for an application, some important influencing parameters need to be considered:

a) concrete properties,

b) nail design and features

c) the fastening system used

d) nail embedment depth and

e) fastening tools and energy level

a) Concrete properties

A nail penetrating concrete needs to create a hole for the shank by crushing and compacting the concrete and also needs to withstand hitting hard aggregates. The resulting holding value achieved by the nail is linked to its diameter and embedment depth.

High penetrability and compactability lead to high stick rates and holding values.

Note: Compressive strength alone is not decisive for nail performance.

Aggregate — Concrete matrix — Embedment
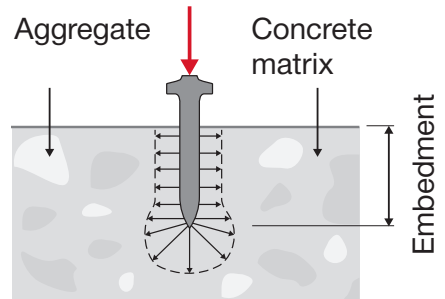
Three concrete types are being distinguished:

S Soft	• Low compressive strength, e.g. $f_{c\ cube}$ = 20 – 45 MPa • Small to medium-size aggregates, e.g. soft limestone • Example: Lightweight concrete	
T Tough	• Medium to high compressive strength, e.g. $f_{c\ cube}$ = 45 – 60 MPa • Medium size aggregate, e.g. lime, stone, pit gravel • Example: Normal weight concrete	
V Very Tough	• High compressive strength, e.g. $f_{c\ cube} \geq$ 60 MPa • High proportion of large and mainly hard aggregates, e.g. quartz, granite • Example: High performance concrete, very old concrete.	
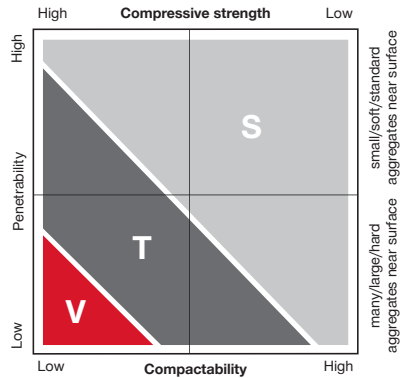
Note: $f_{c,\ cube}$ = Compressive strength of concrete cube (150 mm edge length)

b) Nail design and features

Penetrability and compactability, i.e. a nail's ability to penetrate and compact the concrete, are strongly influenced by three nail design features:

Tip Shape

The shape and the reduction of the diameter in the area of the tip allows a significantly improved penetration behaviour in concrete.

Better ability to penetrate concrete

Cut   Ballistic   Stepped shank   Long conical

Nail geometry

Length and diameter also affect how easily the nail penetrates the concrete.

Nail Hardness

A harder nail is easier to drive into tougher concrete. However, if the nail is too hard, it can break instead of bending when it hits a hard aggregate in the concrete.

c) Fastening systems

Hilti Direct Fastening system help to ensure that nails are correctly driven by achieving maximum nail perpendicularity, good nail guidance and thorough use of the appropriate driving energy.

Perpendicularity

Hilti Direct Fastening tools help to keep nails perpendicular to the working surface, thus eliminating failures caused by attempting to drive the nail at an angle. During the fastening process, Hilti Direct Fastening tools have be maintained perpendicular to fastened material as mush as possible. Please refer to product IFUs and tool operation manuals for details.

Nail guidance

Due to excellent nail guidance in the tool and the use of solid washers, the nail leaves the tool at the intended angle.
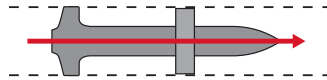
d) Nail embedment depth

Another factor that influences nail performance is depth of embedment. A nail that can be driven deeper has the ability to hold higher loads. However, there are two side effects if a nail needs to be driven deeper.

- The stick rate can decrease
- Higher driving energy is required as the nail has to penetrate further into the concrete.

e) Fastening tool and energy

The nail driving energy released by a Hilti tool is precisely controlled to ensure reliable achievement of the desired embedment depth.

Powder-Actuated Tools (PAT)

Embedment depth of a nail can be influenced by selecting the right cartridge color and adjusting the power setting of Powder-Actuated Tools (PAT) on concrete.

Hence, it is crucial to understand how the different tools in combination with the various cartridges vary in terms of energy generation. And use that knowledge to pick the right tool and the right cartridge to achieve the required embedment depth to create the optimum nail performance.

Gas tools

Embedment depth can be influenced by adjusting the slider in the front of the tool to "+" or "-" position.

Battery tools

Embedment depth can be influenced by selecting a different nail length.

Choice of a nail for use on concrete

The three main factors that define the nail selection on concrete are

•	stick rate (i.e. the percentage of nails that hold securely after fastening),

•	holding values and

•	the cost of the nail.

Stick rate

90%

The stick rate indicates the percentage of nails that were driven correctly to carry a load.

Generally, stick rate can often be improved by combination of

•	using shorter nails (on condition that required load can still be achieved with shorter embedment)

•	selecting nails from a higher nail class (nail classes are described in later section of this chapter)

•	using more energy which can be achieved by combination of tools, cartridges and energy setting

•	using different technology and nails from a higher nail class, i.e. switching from gas and battery tools and nails to Powder-Actuated Tools (PAT) and nails.

Holding values

Holding values provide a measure of a nail's load-bearing capability which ensures the reliable use in practical application(s), consistent with their diameter and embedment depth. Nails are subject to static or quasi-static actions tension, shear or combined tension and shear.

Tension   **Shear**
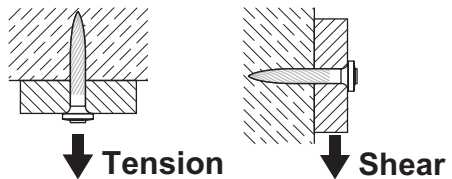
Cost of the nail

The wide range of Hilti nails offers the most cost efficient solution for various applications by allowing selection of exactly the right nail based on application requirements.

Types of nail classes

Different nails have been developed for various applications and conditions.

Medium duty Class I and II nails are used for load-sensitive high performance applications in tough and very tough concrete, while medium duty Class III nails are for versatile use in soft and tough concrete. Medium duty Class I, II and III nails are generally fastened with Powder-Actuated Tools (PAT).

Light duty Class IV and V nails, generally fastened with gas and battery tools, are typically used for applications that have lower load requirements, hence requiring shorter embedment depth. In general, Class V nails present the most economical solution as they are the least costly.

Cost is directly related to
•   the manufacturing technologies involved as well as
•   the material from which the nails are made.

Each higher nail class performs better under harsher conditions than the one below, but the manufacturing costs, and thus the price of the nail, increase with each nail class.

	Nail Class	Nail featured			Concrete Class	Nail examples	Applications
		Ø [mm]	Hardness [HRC]	Tip			
Medium duty	Class I	> 4.0	> 58	Long conical	S T V	X-AL-H [1]	Load sensitive high performance and special applications in tough and some very tough concrete.
	Class II	4.0	Up to 60	Ballastic or better	S T	X-P X-U	Load sensitive high performance applications in tough concrete.
	Class III	3.5 to 3.7	Up to 58	Mostly cut	S T	X-C	Versatile use in soft and tough concrete.
Light duty	Class IV	3.0 to 3.2	Up to 58	Ballastic or better	S T	X-P G2/G3/B3	Use in soft and some tough concrete with shorter embedment, e.g. for track fastening to slab underside.
	Class V	2.6 to 3.0	Up to 57	Mostly cut	S	X-C G2/G3/B3	Use in soft concrete with shorter embedment, e.g. for track fastening.

[1] X-AL-H nail is pre-mounted to X-CX ceiling fasteners

Nail class versus concrete type

Stick rate versus holding values of nail classes

Nail classes are clearly differentiated when faced with tough and very tough concrete. Premium nails perform better than their less costly counterparts.

Depth of embedment, nail geometry, hardness and tip shape vary between nail classes.
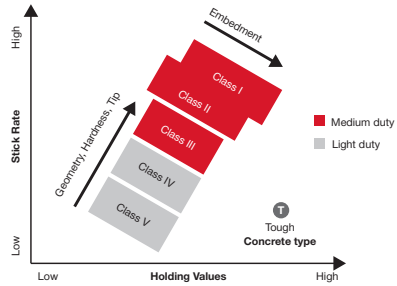
Stick rate of nail classes in different concrete types

Nail performance varies depending on the toughness of the concrete and the distribution of its aggregates. Nails of all classes perform similarly in soft concrete, but as the concrete gets tougher, the stick rate varies.

Guidelines to selecting the right nail for concrete

- Understand the application
- Be specific about important application requirements
- Get to know the Hilti range of nails
- Choose the right nail based on application requirements

Improving the stick rate can be done in three different ways:

1. Use a shorter nail (if required embedment / load still can be reached with shorter nail)
2. Select a nail from a higher nail class (move from Nail Class III to II)
3. Use more energy (energy setting) / select different technology

Example of nail selection process to improve stick rate.

Indicative Stick Rate ranges per Nail Class in Tough Concrete

	Nail	
Class II	X-P 27 MX	
	X-U 27 MX	
Class III	X-C 27 MX	
	X-C 20 MX	
Class IV	X-P 20 G3	
Class V	X-C 27 G3	
	X-C 20 G3	

Stick Rate

- Maximize the stick rate
- Achieve the required holding values
- Select the most cost-efficient nail
- Achieve optimum embedment depth based on selecting the appropriate cartridge and adjusting the power setting for DX systems.
  - No power and cartridge selection required for GX and BX systems.
- Other application relevant requirements, e.g. environmental conditions, corrosion, etc., must be considered.