HILTI CONCRETE SENSORS

Technical Summary

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STRENGTH / MATURITY

General

Hilti Concrete Sensors enables contractors to monitor the in-situ strength of concrete in real-time.

When concrete ingredients are mixed with water, the mixture begins to set and gain compressive strength, also known as “curing”. The compressive strength is typically measured in either pounds per square inch (PSI) or megapascals (MPa). The warmer the ambient conditions, the faster it will gain strength. The cooler the ambient conditions, the slower it will gain strength.

The term “maturity” refers to strength gain over a period of time. The industry standard cure time to reach the minimum design strength is 28 days.

For cast-in-place concrete on a jobsite, it can be beneficial to monitor the in-situ strength, not only to help ensure proper curing, but also to schedule work as efficiently as possible. For any strength data reported in the Hilti Concrete Sensors software, it’s the discretion of the customer and appropriate project stakeholders to make decisions for the project based on this information.

Hilti Concrete Sensors Lab Services

The most widely accepted industry standard to monitor in-situ strength is ASTM C1074 Maturity Method. This standard requires an upfront “calibration” test for each unique mix design. There are two types of tests within this standard. The Equivalent Age (aka Arrhenius equation) test requires batching, casting, curing and crushing (aka breaking) cylinder and cube specimens, within a cure time of 28 days. Cylinders are cured at room temperature and cubes are separated into groups and cured at a minimum of 3 different temperatures. This is to determine the temperature sensitivity based on the chemistry of the mix design. Hilti Concrete Sensors performs the Equivalent Age test, but at 4 different temperatures, in order to increase accuracy. The less comprehensive Time-Temperature (aka Nurse Saul) test requires batching, casting, curing and crushing only cylinders, which are only cured at 1 temperature and is therefore more limited in accuracy when the in-situ concrete temperatures on the project experience fluctuations.

This upfront testing requires our team to work with the appropriate project stakeholders to confirm mix design batching instructions and list of materials and then obtain those materials to conduct the 28-day test. Once the test is completed, the mix design ID number is added to our in-app library under the supplier’s company name.

To confirm accuracy, it’s recommended by ASTM to conduct a verification exercise consisting of a project stakeholder in the field adding sensors to typical cylinders being cast onsite by the project’s third party lab technician, so the strength data reported in the app can be compared to the third party lab’s physical cylinder break results.

It’s important to note, when a significant change is made by the supplier to a mix design already in our in-app library, the strength data reported by our software will not be accurate and new testing (“calibration”) will be required.

TEMPERATURE

Hilti Concrete Sensors enables contractors to monitor the in-situ temperature of concrete in real-time.

Monitoring internal concrete curing temperature (and temperature differentials between multiple points within the concrete) can help ensure proper curing and achievement of the minimum design strength. It also helps ensure compliance with building code, specifications, industry standards and thermal control plans. Thermal control plans are guidelines for contractors to execute proper curing and are typically written by an engineer.

One example of an industry standard contractors must comply with, is ACI 306R (Cold Weather), requiring them to manage the curing process in such a way that the internal concrete curing temperature stays within certain thresholds.

Another example is ACI 207.1 / ACI 116 (Mass Concrete) which requires contractors to manage the curing process for extra thick (typically 3+ feet) concrete in such a way to prevent the temperature differential from center to surface from exceeding a specified threshold and to prevent the center temperature from exceeding a specified threshold. Management of the mass concrete curing process might include a specialized mix design, cooling the interior of the concrete or warming the exterior of the concrete.

Our sensors record and store a temperature datapoint every 15 minutes which is used for the temperature reports/alerts and for calculating the strength data as referenced above.

RELATIVE HUMIDITY

Hilti Concrete Sensors enables contractors to monitor the in-situ Relative Humidity (RH%) of concrete in real-time.

RH% is a critical measurement in ensuring proper adhesion of finishes to the surface of concrete (ie: flooring, roofing, paints, coatings). Contractors can benefit from monitoring RH% during the drying process (which typically takes many months) in order to more efficiently schedule the respective subcontractor's independent test and application of finishes, but also to retain supplemental data in case of the need for conflict resolution if an application fails.

The concrete drying process:

- The rate at which concrete loses moisture is affected by many variables, including but not limited to temperature, ambient humidity, exposure to elements, air flow, slab thickness, mix design, and one-versus-two sided evaporation
- The RH% of freshly poured concrete is 100%
- For concrete that remains exposed to the elements, the RH% will remain at 100% indefinitely
- When concrete is permanently protected from the elements and in climate-controlled conditions, it may take 10+ months for the sensors to report a drop from 100%
- Our sensor data may not accurately reflect RH% across an entire area if conditions aren't maintained and/or in the event of localized moisture exposure, such as a water spill

RH% monitoring is almost exclusively used for slabs that are intended to receive finishes. In order to optimize accuracy in monitoring RH% with our sensors, installation depth in a slab which is drying from the top side only (ie slab on metal deck, slab on grade), should be 40% down from the top. For a slab which is drying from both top and bottom (ie elevated slab after stripping formwork) installation should be 20% down from the top. IMPORTANT: Do not exceed 6" sensor depth from surface because it will impede the wireless signal.

RH% measurements are a local measurement to a sensor, and many sensors are necessary to derive an overall estimate of drying progress across an entire slab. Sensors should be spaced out evenly and installed at the same depth for consistent results.

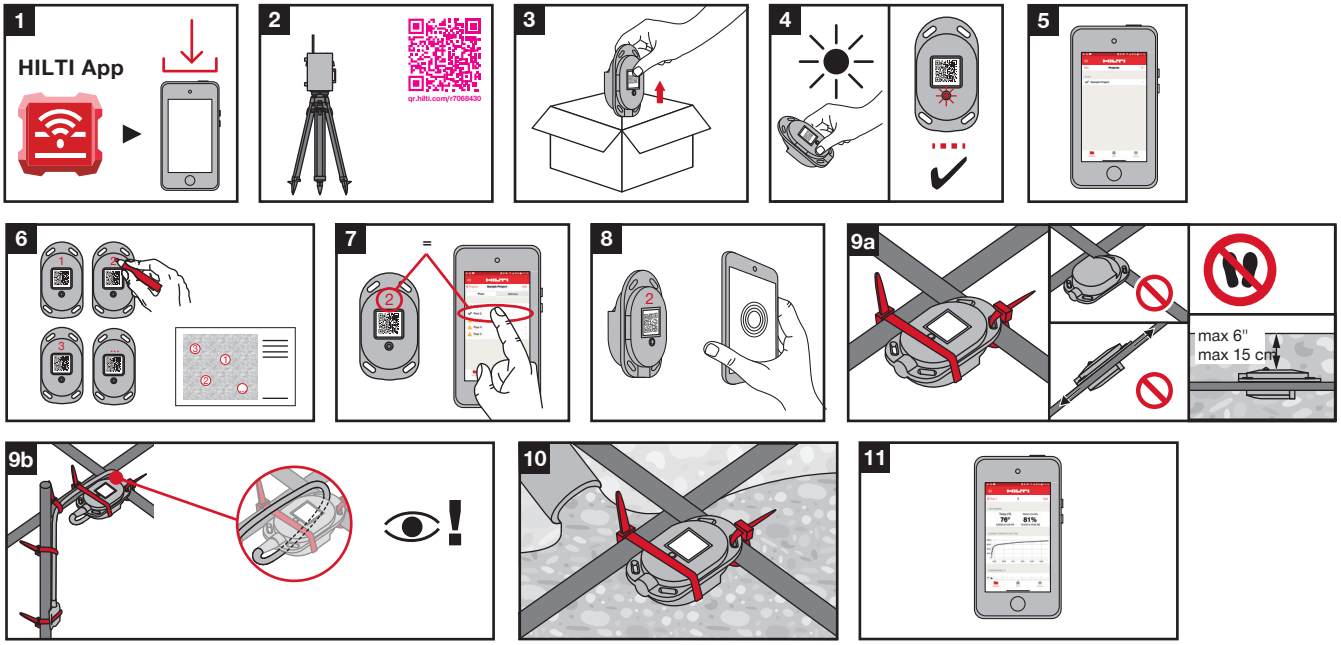
Our sensors record RH% and temperature sample pairs (1 RH% plus 1 Temp reading) every 6 hours: 4 sample pairs per day (these samples are separate from the 15-minute temperature sampling).

HILTI CONCRETE SENSORS HARDWARE & SOFTWARE

Sensors

Sensor Models			
Sensor Model	**Data Collection Method**	**Data Measured / Reported**	**Installation Max Depth**
HCS T1	Bluetooth	Strength, Temperature	6"
HCS TH1	Bluetooth	Strength, Temperature, Relative Humidity	6"
HCS T1-B3	Bluetooth	Strength, Temperature	3'6"
HCS T1-B8	Bluetooth	Strength, Temperature	8'6"
HCS T1-B15	Bluetooth	Strength, Temperature	15'6"
HCS T2	Long Range	Strength, Temperature	6"
HCS T2-B3	Long Range	Strength, Temperature	3'6"
HCS T2-B8	Long Range	Strength, Temperature	8'6"
HCS T2-B15	Long Range	Strength, Temperature	15'6"

Sensor instructions



Step 1:
Download Hilti Concrete Sensors app (available from iOS and Android)

Step 2:
If using Bluetooth sensors, please skip this step.
If using Long Range data collection option with a Gateway, please follow Gateway setup instructions.

Step 3:
Remove sensors from their packaging, which you intend to install in your upcoming concrete pour.

Step 4:
Activate sensors by exposing them to a bright light. If red indicator LED isn't blinking, try using a flashlight or direct sunlight.

Step 5:
Follow in-app instructions to add a Project and respective concrete Pours. Including the Pour name and date. (Android: Use plus (+) sign to add)

Step 6:
Check pour area on floorplan and decide on intended sensor locations. Label surface of each sensor with its intended name. Clearly mark floorplan hardcopy to show each sensor name/location. (Optional: see in app instructions on how to add the floorplan and pin each sensor location).

Step 7:
Select Pour which the sensors are intended for. Select Add Sensor. (Android: Use plus (+) sign to add)

Step 8:
Scan QR code, enter sensor name and Save.

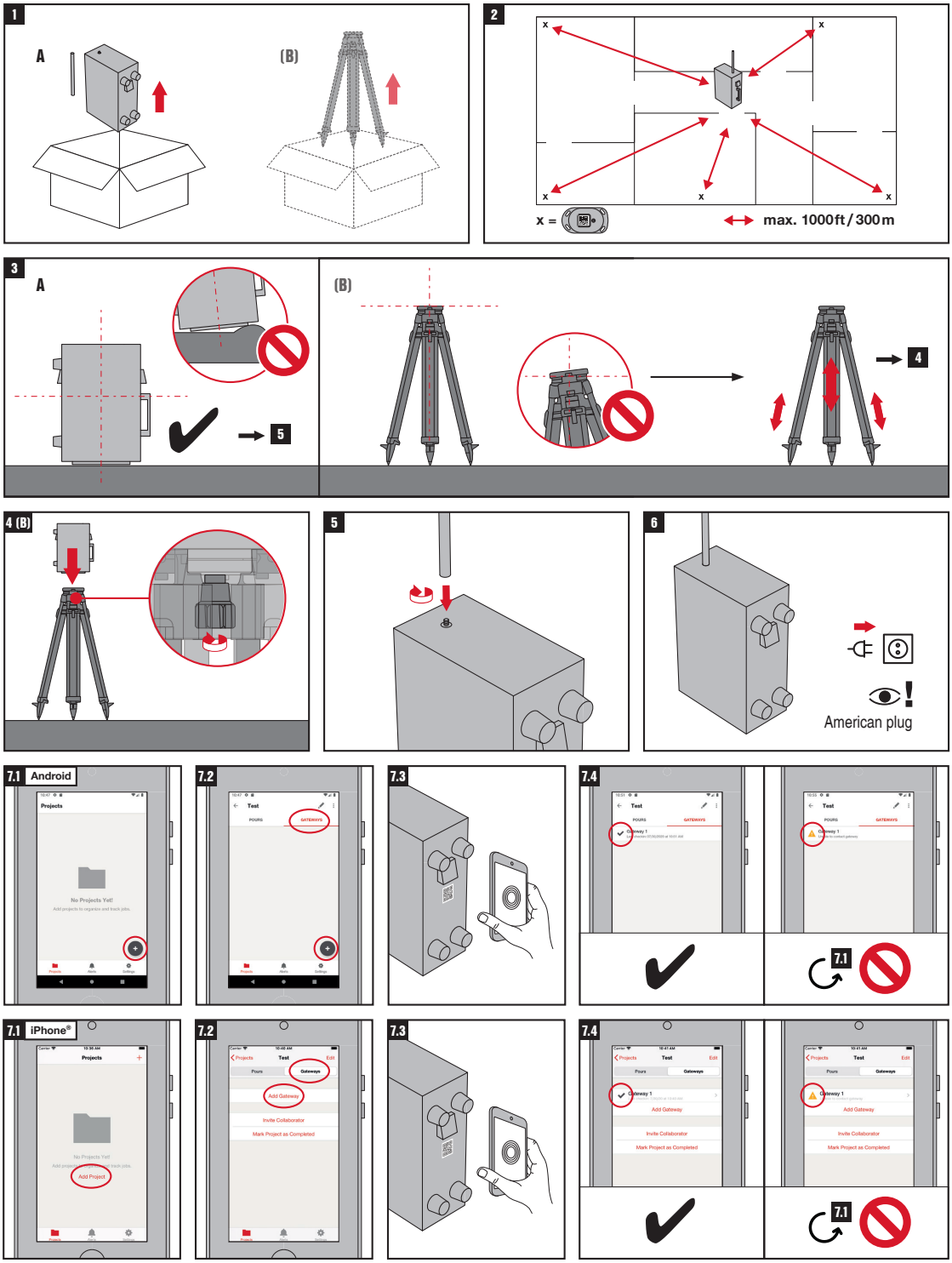
Step 9a:
Secure sensor to rebar or mesh at intersection for stability and fasten at minimum two points. IMPORTANT: Ensure QR code is facing upwards. Be careful not to step on sensors. Sensor can be no deeper than 6" from surface of concrete.

Step 9b:
For sensors with cable and temperature probe ("B-side"), ensure the large end (radio transmitter) is near the concrete surface (max depth for transmitter is 6"). Ensure cable is looped (see image 9b) around rebar in such a way to avoid pull-out during concrete pour. Fasten temperature probe ("B-side") at intended monitoring point and secure cable to rebar.

Step 10:
Pour Concrete

Step 11:
Connect to sensors as often as needed to monitor progress. Sensors store all data onboard for life of battery (~2 years) and will also be stored in the mobile app once collected.

Gateway instructions



Step 1:
Remove gateway and antenna from packaging. If using tripod, remove from packaging.

Step 2:
Determine best location for gateway with lowest likelihood of sustaining damage, near consistent power, no more than 1,000ft from intended sensor locations (always follow the instructions provided with the gateway).

Step 3:
If not using tripod, determine safe flat dry surface to place gateway. If using tripod, set up level and plumb and secure legs and feet.

Step 4:
Fasten gateway to tripod using provided bolt.

Step 5:
Screw on antenna to top of gateway.

Step 6:
Plug in gateway.

Step 7.1:
Open mobile app and select project (or add new project).

Step 7.2:
Go to Add Gateway

Step 7.3:
Scan QR code on back of gateway and enter desired gateway name and select Save.

Step 7.4:
After a few minutes, a green check should appear in the app — if not, check both power supply and cell coverage for the area and try again. If green check cannot be achieved, please contact Hilti.

LIMITATIONS AND OTHER IMPORTANT INFORMATION

- For a typical slab placement size (approx 10,000-30,000 sq. ft.), a quantity of 5 sensors will typically provide an accurate reading of the entire area (1 sensor per corner, 1 in center). For smaller or larger slab placements, fewer or more sensors may be needed. Engineer of Record (EOR) should always be consulted.

- Redundant sensors at each location are not required, unless contained in project specifications/drawings/thermal control plan.

- Wireless signal strength can be affected by damage to a sensor, distance, sensor depth, formwork, standing water, ice, equipment, materials, etc.

- When none of the above-reference factors are affecting the wireless signal, Bluetooth range is up to 100 feet from mobile device and Long Range is up to 1,000 feet from the gateway.

Hilti, Inc.
1-800-879-8000 | en español 1-800-879-5000
www.hilti.com

Hilti (Canada) Corporation
1-800-363-4458
www.hilti.ca

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