

TECHNICAL  
SPECIFICATION

V2.0



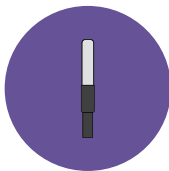
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## Overview

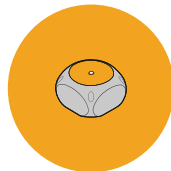
### 0.1. The Converge

The Converge System (the “System”) is a hardware and software product that enables wireless monitoring of concrete temperature and compressive strength (when the correct calibration data is provided for a particular mix design). The System is made up of five parts:

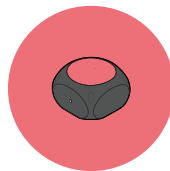
1. The Converge Sensor (the “Sensor”, a temperature Sensor on a 3m cable).
2. The Converge Node (the “Node” connects to Sensors to transmit their data back to Converge Repeaters or Converge Hubs).
3. The Converge Repeater (the “Repeater”, extends range of any Nodes in its’ vicinity by repeating the Node’s signal to other Converge Repeaters and any Converge Hub).
4. The Converge Hub (the “Hub”, a 3G cellular gateway which receives data from Nodes and sends it to the Converge Platform).
5. The Converge Platform (the “Platform”, which allows a user to view and analyse the data from Sensors and set alerts when certain thresholds are met).



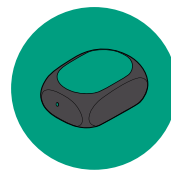
**Sensor**



**Node**



**Repeater**



**Hub**

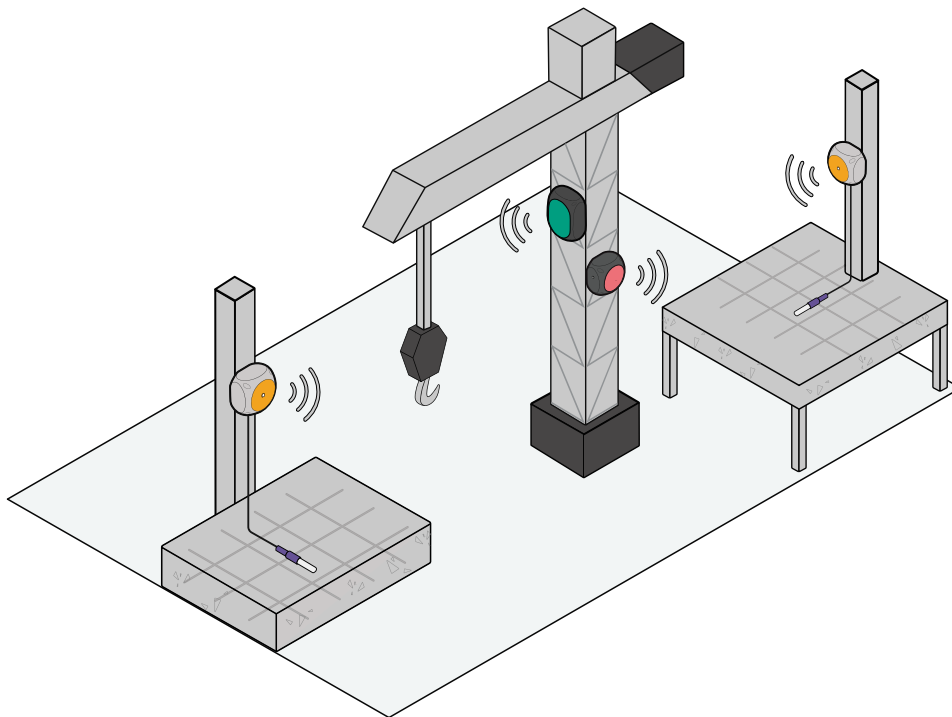


**Platform**

## 0.2. The Basis of the Converge Network

The System requires a Hub to be installed on site, which will form the basis of the Converge Network (the “Network”). The System only supports a single Hub per site, and each Hub can maintain up to 60 simultaneous connections to Nodes or Repeaters.

Converge’s Network operates a mesh topology. Repeaters will form a mesh network on site, and data will be able to hop from one Repeater to the next until it makes it to a Hub. The Network supports a maximum of ten hops (i.e. data from a Node can make its way across ten Repeaters). An example of how a Converge network might be set up can be found in the diagram below:

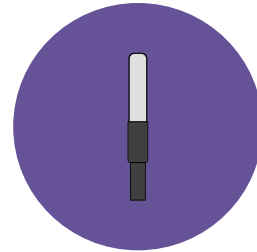


A detailed specification is provided in this document for each component of the System, as well as general instructions on the usage of the Converge System.

## 1. The Converge Sensor

### 1.1. Description

The Converge Sensor is a cable assembly with a temperature Sensor encased within a metal bullet at one end, and a waterproof connector on the other end. The Sensor has a label with a QR code which uniquely identifies the Sensor and allows user to register it and name it on the Platform. The cable length is standardised at 3m, with a cable thickness of 6mm. If a longer cable is required, Converge is able to supply an Extension Cable (see accessories).



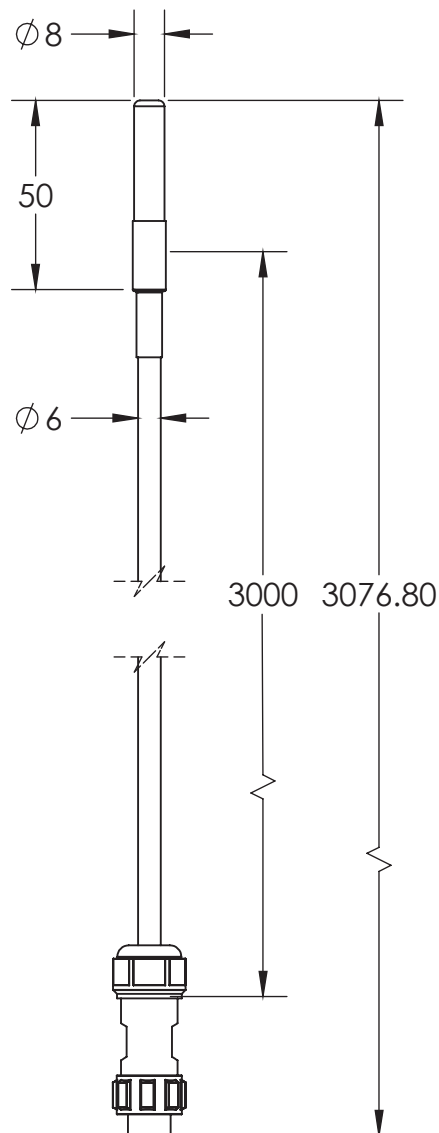
### 1.2. Installation

The Sensor is typically attached to reinforcement at a predefined location inside a concrete slab before any concrete has been poured. The location of the Sensor is determined by the site team. Often more than one Sensor is placed inside a concrete slab. The QR code on the label is then scanned using an internet connected smartphone and the Sensor is registered and named on the Platform so it can be uniquely identified. Once the Sensor has been installed and registered, the Sensor must be connected to a Node to ensure that data is logged and transmitted back to the Platform.

### 1.3. Technical Specifications

Performance	
Approx. lifetime	~ 10 years
Operating temperature	-55 °C ~ +120 °C
Operating humidity	20 ~ 90% RH non-condensing
IP Rating	IP67 (not certified)

Physical properties	
Dimensions	Cable: $\varnothing 6$ mm x 3 m, Sensor housing: $\varnothing 8$ x 50 mm
Weight	160 g



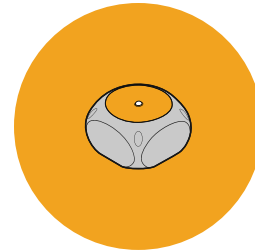
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**Date** 08/05/2017

## 2. The Converge Node

### 2.1. Description

The Node is a data logging device and wireless transceiver. It connects to the Converge Sensor through a waterproof connector, and samples the Sensor every 20min, transmitting that data to the Platform through Repeaters and the Hub on site. The Converge Node includes on-board memory and will cache Sensor data locally if network connectivity is unavailable (up to 10'000 data points can be stored locally). It is powered by two AA alkaline batteries and has a battery life of 2 years.



### 2.2. Installation

The Node is a plug and play device. Once connected to a Converge Sensor, it will start transmitting data to any nearby Repeaters or Hubs (see range considerations further down in this document).

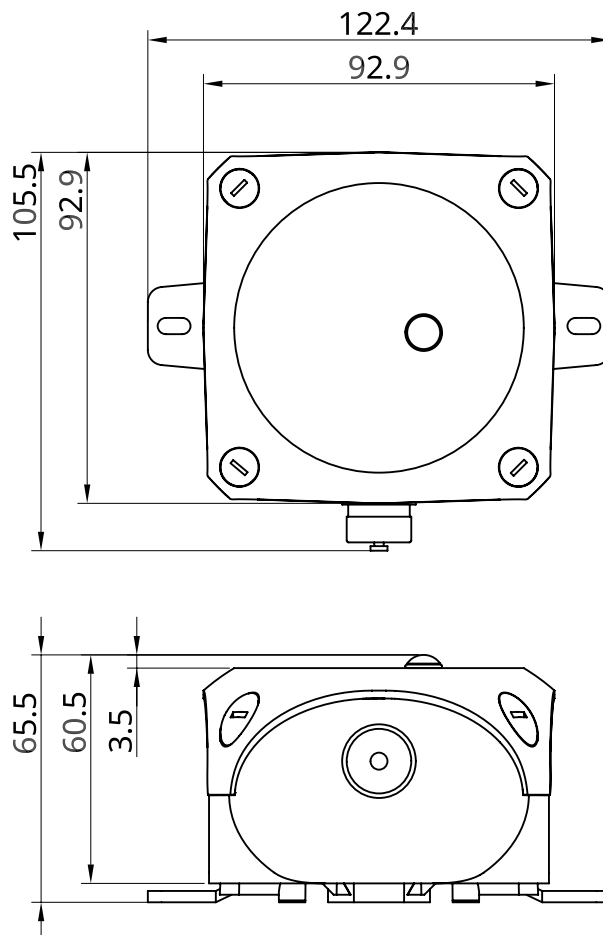
The LED on top of the Node (see diagram below) acts as a status indicator. Nodes that are not connected to any Sensor will be in standby mode. In this mode, the LED should blink blue. When a Sensor is connected to the Node, it will start searching for the network, and the LED will start blinking red. Once it has found the network, the LED will start blinking green. If the LED is not blinking, then the batteries must be replaced (if the batteries are replaced but the LED is still not blinking, this is a sign that the device might be faulty. Please contact converge at [help@converge.io](mailto:help@converge.io) if this occurs). If a Node does not find the network (and keeps flashing red) then this is a sign that the Node is too far away from Repeaters or your Hub. You must either place the Node closer to your existing Repeaters/Hub, or add as many intermediary Repeaters as necessary to ensure you have coverage in your desired location (see section on range below).

The Node can be fixed to various different items, including but not limited to protruding reinforcement, edge protection or formwork (and more importantly, an item that will not be interfered with or moved during the period you will be monitoring your pour). It can be attached using cable ties or tie wire passed through the mounting flanges on the Node enclosure (see diagram below).

### 2.3. Technical Specifications

Performance	
RF Spectrum	868.1 - 868.5 MHz
Operating temperature	-10 °C ~ +55 °C
Operating humidity	20 ~ 90% RH non-condensing
Batteries	2 x AA, ~ 2 years
LED	Blue - Standby, Red - Trying to connect, Green - Connected
Button	N/A
IP rating	IP67 (not certified)

Physical properties	
Dimensions	Main body: 93 x 93 x 62 mm
Weight	180 g



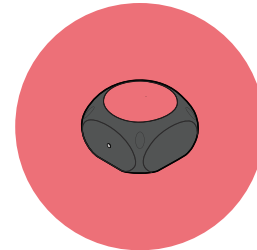
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## 3. The Converge Repeater

### 3.1. Description

The Repeater is a wireless signal booster that allows you to repeat the signal from a Node or a Repeater to other Repeaters and/or a Hub. It is powered by 2xD cell alkaline batteries (user replaceable) and lasts approximately 2 months on battery. It can be turned on using the button on the device and has an LED on the side that acts as a status indicator for network connectivity. The System supports the use of up to ten Repeaters in series (i.e. the 'depth' of the Network is a maximum of 10 hops).



### 3.2. Installation

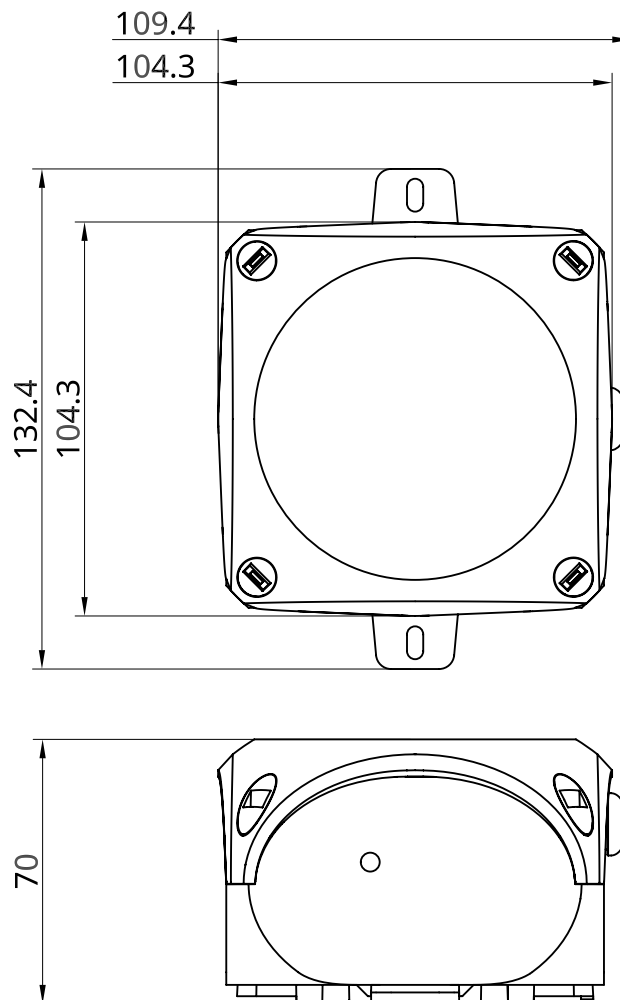
The Converge Repeater is in low-power standby mode by default (the LED will flash blue). It can be turned on by three consecutive presses of the button (the button must be pressed three times within a one second interval). At this point the LED will start blinking red which indicates the Repeater is searching for the network. Once the Repeater has joined the network, the LED will start blinking green. If the Repeater keeps flashing red, this indicates you are too far from other Repeaters or the Hub (see chapter on RF range further below) and you must either move the Repeater closer to them, or add an intermediary Repeater. The Repeater can be turned back into standby mode by three quick consecutive presses of the button.

The Repeater can be fixed to various different items depending on the layout of your sites, including but not limited to cranes, handrails, hoardings, edge protection (and more importantly, an item that will not be interfered with or moved during the period you will be monitoring your pours). It can be attached using cable ties or tie wire passed through the mounting flanges on the Repeater enclosure (see diagram below).

### 3.3. Technical Specifications

Performance	
RF Spectrum	868.1 - 868.5 MHz
Operating temperature	-10 °C ~ +55 °C
Operating humidity	20 ~ 90% RH non-condensing
Batteries	2 x D, ~ 2 months
LED	Blue - Standby, Red - Trying to connect, Green - Connected, RGB - Low battery
Button	On/Off: 3 presses (each within 1s of the previous)
IP rating	IP67 (not certified)

Physical properties	
Dimensions	Main body: 104 x 104 x 70 mm
Weight	450 g



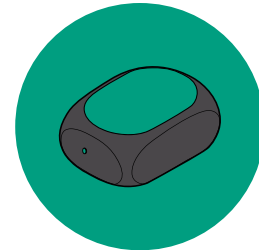
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**Date** 08/05/2017

## 4. The Converge Hub

### 4.1. Description

The Converge Hub is a wireless transceiver which receives all the sensor data from Nodes and Repeaters on site, and sends them to the Platform over the cellular network. It requires access to a continuous, stable and uninterruptible power source (110V, 16A plug standard) and reliable cellular connectivity (We use “3” in our standard Site Pack in the UK, but other cellular connectivity providers can be used if needed). The Hub has three antennae (two for cellular connectivity, one for the local Converge network) which are colour coded to the appropriate sockets on the Hub. It is important that the correct antenna is installed in the correct socket. If the Hub loses access to power, it will attempt to notify Converge and a notification will appear on the Platform.



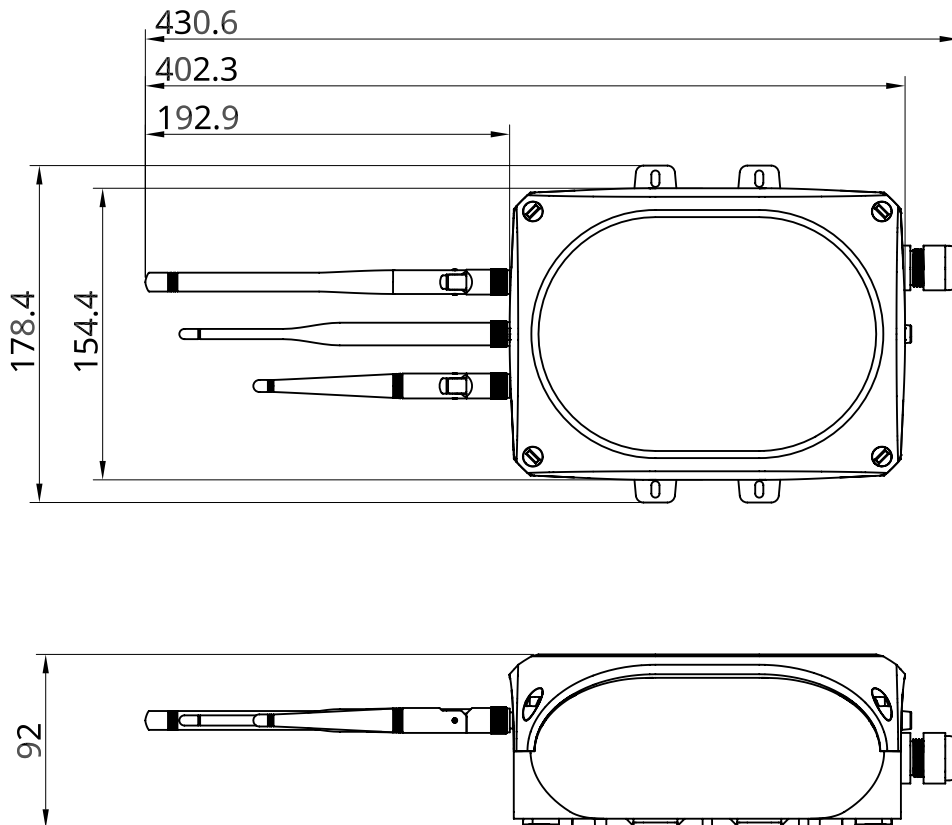
### 4.2. Installation

The three antennas must be screwed into the connectors on the Converge Hub (connectors on the top side of the enclosure, colour coded to match each relevant antenna). Once the antennae have been installed, the Hub must be plugged into a continuous, stable and uninterruptible power source (110V 16A socket as is commonly found on site is usually sufficient). Ideally the Hub should be placed somewhere elevated which overlooks as much of the area where concrete monitoring will be required. The Hub can be fixed using cable ties or tie wire through the flanges on the Hub enclosure. If there is no suitable location to attach the Hub, Converge is able to supply a Hub stand on request. The Hub has an LED on the same face as the power cable (see technical drawing below). When the Hub is first connected to a power supply, the LED will start blinking, which indicates it is looking for a cellular signal and is trying to connect to the internet. If the Hub successfully finds cellular signal and connects to the internet, the LED will stop blinking and remain on. If the LED does not stop blinking there might not be sufficient cellular connectivity at this location with the default network provider. Try moving the Hub to an alternative location. If no signal can be found please contact Converge to discuss possible solutions (cellular antennae, or a different cellular providers could both be good options).

### 4.3. Technical Specifications

Performance	
RF Spectrum	850/868/900/1800/1900 MHz
Operating temperature	0 °C ~ +50 °C
Operating humidity	20 ~ 90% RH non-condensing
Power requirements	Voltage input: 90~264 VAC, 127~370 VDC
	AC frequency range: 47~63 Hz
	Power consumption: < 20 W
	Electric plug: IP44 3P Industrial Power Plug (5m cable, other plug types on request)
Connectivity	GSM/GPRS/EDGE, HSUPA/HSDPA/UMTS, Propetary SubGHz (868 MHz)
LED	Blinking: establishing 3G connection, Steady: 3G connectin established
Aerials	2x cellular antennae, 1x sub-GHz antenna
IP rating	IP 67 (not certified)

Physical properties	
Dimensions	Main body: 154 x 209 x 92 mm
Weight	1775 g



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**Date** 08/05/2017

## 5. The Converge Platform



### 5.1. Description

The Converge Platform offers users the following core product functionality:

- a. Temperature sensors and the supporting hardware infrastructure.
- b. A cloud platform providing:
  - » measurements storage for (as a minimum), the duration of the subscription period.
  - » sensor data access for registered users.
  - » the ability to calculate strength based on the maturity method, see 5.2 for specific maturity functions.
  - » core platform functionality may periodically undergo updates to increase the value and usability of the service, but as a minimum the above will be retained.

### 5.2. Requirements

The Platform is compatible with all modern browsers (latest versions of Chrome, Firefox, Safari and Opera). It is also compatible with Internet Explorer 11 and Microsoft Edge. It should be compatible with Internet Explorer 10 but this is not officially supported. For optimal performance and security, it is recommended that you use the latest versions of Chrome or Firefox. A broadband-speed internet connection is required for the Platform to work, and Javascript must be enabled.

### 5.3. Concrete Strength Calculation

#### 5.3.1. Maturity functions

Three maturity functions are available through the Converge platform. Each of these functions can be used to calculate the equivalent age of concrete as a function of temperature and time.

#### Nurse-Saul equivalent age function

$$\text{Equivalent Age (hours at } 20^{\circ}\text{C)} = \sum_{t=0}^t \frac{\theta - DT}{RT - DT} \cdot \delta t$$

Where:

$\theta$  = Average temperature during time interval,  $\delta t$

$DT$  = Datum temperature

$RT$  = Reference temperature ( $20^{\circ}\text{C}$ )

#### Sadgrove equivalent age function

$$\text{Equivalent Age (hours at } 20^{\circ}\text{C)} = \sum_{t=0}^t \left( \frac{\theta + 16}{RT + 16} \right)^2 \cdot \delta t$$

Where:

$\theta$  = Average temperature during time interval,  $\delta t$

$RT$  = Reference temperature ( $20^{\circ}\text{C}$ )

#### Arrhenius equivalent age function

$$\text{Equivalent Age (hours at } 20^{\circ}\text{C)} = \sum_{t=0}^t e^{\frac{-EA}{R} \left[ \frac{1}{273+\theta} - \frac{1}{273+RT} \right]} \cdot \delta t$$

Where

$\theta$  = Average temperature during time interval,  $\delta t$

$EA$  = Activation energy (J/mol)

$R$  = Universal gas constant (8.314 J/(mol.K))

$RT$  = Reference temperature ( $20^{\circ}\text{C}$ )

### 5.3.2. Fitting functions

Three fitting functions are available through the Converge platform. Each of these functions is used to represent the strength-maturity relationship for a given concrete. The function is used to calculate the compressive strength of concrete as a function of its equivalent age (which in turn is a function of temperature and time).

#### Logarithmic function

$$S = a \cdot \ln(\theta) + b$$

Where:

$\theta$  = Equivalent age (hours at  $20^{\circ}\text{C}$ )

$S$  = Compressive strength (MPa)

$a$  = Slope

$b$  = Y-Intercept

#### Hyperbolic function

$$S = S_u \cdot \frac{k \cdot (\theta - M_0)}{1 + k \cdot (\theta - M_0)}$$

$\theta$  = Equivalent age (hours at  $20^{\circ}\text{C}$ )

$S$  = Compressive strength (MPa)

$S_u$  = Limiting compressive strength

$M_0$  = Maturity when strength begins

$k$  = Rate constant (initial slope)



**Exponential function**

$$S = S_u \cdot e^{-\left(\frac{\tau}{\theta}\right)^\alpha}$$

Where

$\theta$  = Equivalent age (hours at 20°C)

$S$  = Compressive strength (MPa)

$S_u$  = Limiting compressive strength

$\tau$  = Characteristic time constant

$\alpha$  = Shape parameter

## 6. Accessories

### 6.1. Sensor Extension

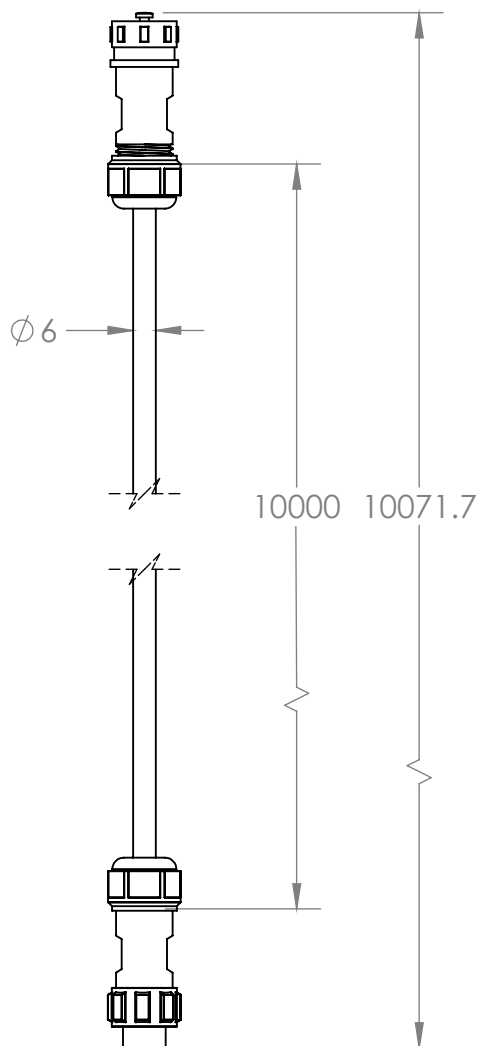
#### 6.1.1. Description

Sensor Extensions are a male to female, 10m cable assembly which allows the extension of a Sensor. Multiple Sensor Extensions can be used together (we support the use of up to four in a row) to extend the length of a Sensor by up to 40m. This is particularly helpful if you're looking to monitor deep piles or other large concrete elements.

#### 6.1.2. Technical Specification

Performance	
Approx. lifetime	~ 10 years
Operating temperature	-55 °C ~ +120 °C
Operating humidity	20 ~ 90% RH non-condensing
IP Rating	IP67 (not certified)

Physical properties	
Dimensions	Cable: $\varnothing 6$ mm x 10 m
Weight	500 g



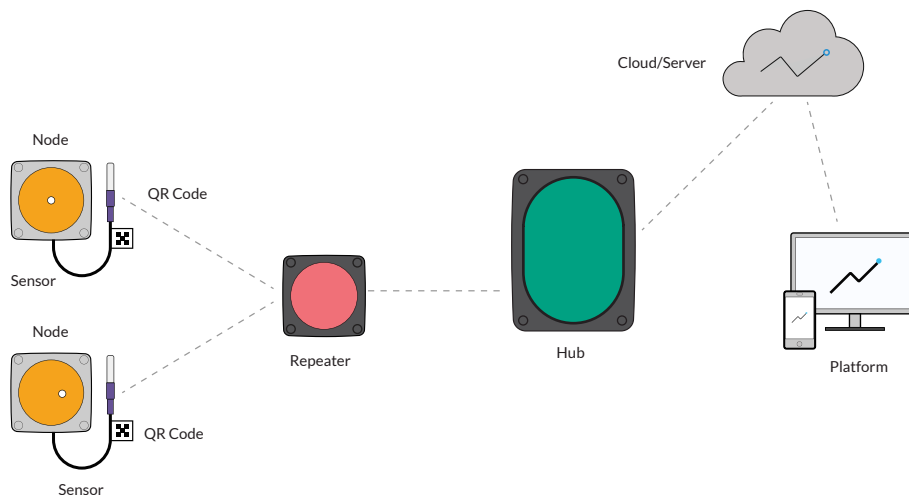
**Scale** 1:2

**Date** 08/05/2017

## 7. Operating the Converge System

### 7.1. The Converge Network

The Converge Network operates on a mesh networking topology. Nodes can send data to Repeaters or Hubs. Repeaters can send data to other Repeaters and Repeaters can send data to the Hub. The Hub itself requires cellular connectivity to send that data back to the Platform (see figure below). We advise that the infrastructure (the Hub and Repeaters) are set up on site in advance. On a wide site, installing the Repeaters on cranes usually ensures coverage across the site. On a tower, the Repeaters can often be installed on edge protection and also placed in and around the core. It is important that repeaters are installed on items that are not likely to move in the near to mid term. More guidance on this is available at [help.converge.io](https://help.converge.io).



For optimal performance we recommend a maximum of 30 meters line of sight between Nodes and Hubs, Nodes and Repeaters, Repeaters and Repeaters, or Repeaters and Hubs. The range of the wireless network will vary on the basis of the environment. For example, large metal cages or thick concrete cores could reduce the range significantly, requiring more Repeaters or a different locations for the devices. Adverse weather (heavy rain or fog) can also have a negative impact on range. A construction site is a dynamic environment and as the environment changes you may need to modify the layout of your Network. If you have any questions about the layout of your infrastructure on site, please do not hesitate to contact us at [help@converge.io](mailto:help@converge.io).