Transactions, **SMiRT-26**
Berlin/Potsdam, Germany, July 10-15, 2022
Division XI

AN INNOVATIVE NON-INTRUSIVE FASTENER TO STREAMLINE NUCLEAR POWER PLANT CONSTRUCTION

Hamza Abbad El Andaloussi[1], Christophe Paillusseau[2]
Alexandre Hamelin[3], Guillaume Plagne[4]

[1] Product Manager, COLD PAD, Paris, FRANCE (haa@cold-pad.com)
[2] VP Sales & Marketing, COLD PAD, Paris, FRANCE (cp@cold-pad.com)
[3] Civil Engineer, EDF – DIPNN DT, FRANCE (alexandre.hamelin@edf.fr)
[4] Engineering Manager, EDF Energy - NNB, UK (guillaume.plagne@nnb-edfenergy.com)

ABSTRACT

Energetic independency is a major challenge for our generation whether it is from an environmental point of view or a geopolitical one. Nuclear power energy is for sure part of the answer to this challenge. Hence, building and maintaining Nuclear power plants on time and on budget becomes a hot topic.
This technical paper presents the benefits offered through the use of C-BLOCK™ - the innovative non-intrusive fastener - for the construction of one of the most advanced nuclear plant worldwide like Hinkley Point C.
First, the paper explains the challenges of post-installation fastening on reinforced concrete. Then, C-BLOCK™ and its key innovative technical aspects are presented. At last, the value proposition of C-BLOCK in terms of planning flexibility, cost savings and health and safety advantages is detailed.
The paper is based on business cases focused on Hinkley Point C project and developed with NNB GenCo (the power utility), the civil engineering contractor, as well as Cold Pad (the technology provider).

STAKES OF POST-INSTALLATION FASTENING ON REINFORCED CONCRETE

A construction project like Hinkley Point C includes not less than 40 000 post-installation mechanical anchor points for the secondary steel works (guardrails, ladders, metallic platforms, etc.) which does not even include the ”Mechanical, electrical and air conditioning” phase. Any error on the positioning of these anchors leads to use of conventional doweling to install new anchor points at the right position as presented in the next figure.

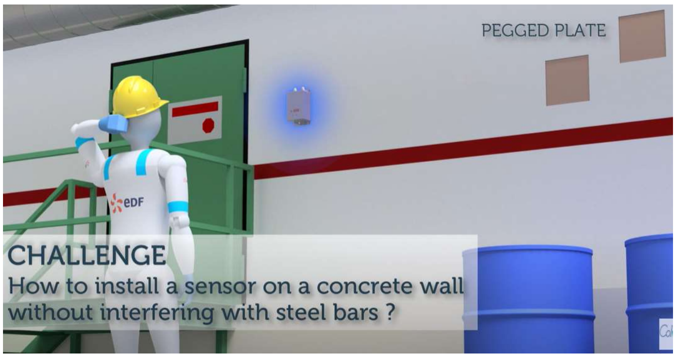


Figure 1. Illustration of the challenge when post-installation anchors are not well positioned.

The conventional doweling methodology is based on drilling the concrete in order to install the anchor point. This requires the preliminary use of **concrete scanner prior to drilling and placing dowels**. Indeed, one of the main stakes of dowelling is to guarantee the integrity of the reinforced concrete after the installation of the anchor point. This sequence of scanning the concrete is painful, time consuming and not cost efficient as the process is not direct between the Engineering teams and the installation teams, many back and forth loops might be necessary between these teams in order to minimize the uncertainty on the positioning of the reinforcements inside the concrete which leads to delays in the project planning.
From a cost perspective, it is typical to consider that one lost day of production equates to a few million euros.

The industry has therefore been looking since a long time for alternatives to dowels which would provide more flexibility in terms of planning and construction. COLD PAD and Electricité de France (EDF) partnered to co-develop C-BLOCK™, a non-intrusive and heavy-duty mechanical fastener bonded "on" concrete rather "in" concrete. This innovation is presented in the next paragraph.

INTRODUCTION TO AN INNOVATIVE AND NON-INTRUSIVE FASTENER

C-BLOCK presentation

In order to both secure construction planning and improve associated costs, COLD PAD and EDF partnered to co-develop C-BLOCK™ a patented non-intrusive, heavy-duty bonded mechanical fastener designed for concrete surfaces with immediate applications for nuclear power plants. The fastener is bonded onto the concrete surface through a hardened adhesive as presented in the next figure.

Figure 2. C-BLOCK™, bonded on concrete surface.

This fastener is a bonded assembly consisting of:

- a circular steel plate with a threaded rod,
- an intermediate deformation layer of polymer,
- a nut and a washer.

The footprint of C-BLOCK™ on the concrete surface is 130 mm. This information are illustrated in the next figure.

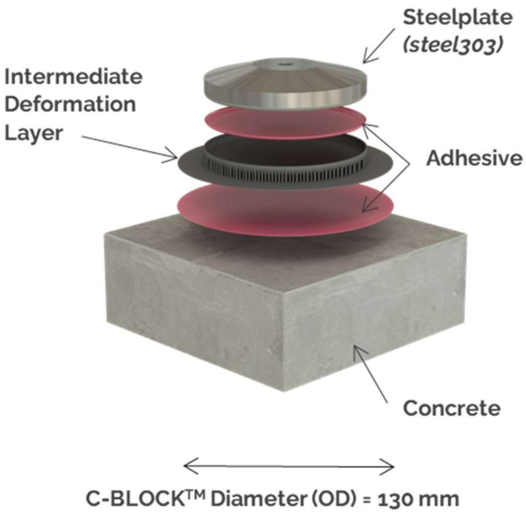


Figure 3. Components of C-BLOCK™ and dimensions.

A first innovative aspect of the C-BLOCK is that the superficial load transfer through the bond line eradicates the need for drilling into concrete then no need for concrete scanning prior drilling. It allows faster, safer an more economic alternative mean of fastening compared with standard dowels.

During the development of C-BLOCK™, one of the main technological locks was to ensure an anti-seismic property essential for the fastener to be used in various applications and locations in nuclear industry. This means that even in case of a seism and the presence of a crack under the fastener, the latter shall present a sufficient residual mechanical capacity. This challenge has been unlocked thanks to the 3D printed intermediate layer (black part of the fastener) that gives sufficient flexibility transversely combined to a relative high stiffness in tension. The 3D pattern / repetitive micro-structures generate the required macroscopic anisotropy. This unique deformation layer is jointly patented with EDF and enables the C-BLOCK to safeguard the integrity of the concrete surface even in case of regulatory crack opening under the fastener. The next figure illustrates the behavior of the intermediate deformation layer in case of crack propagation in the concrete.

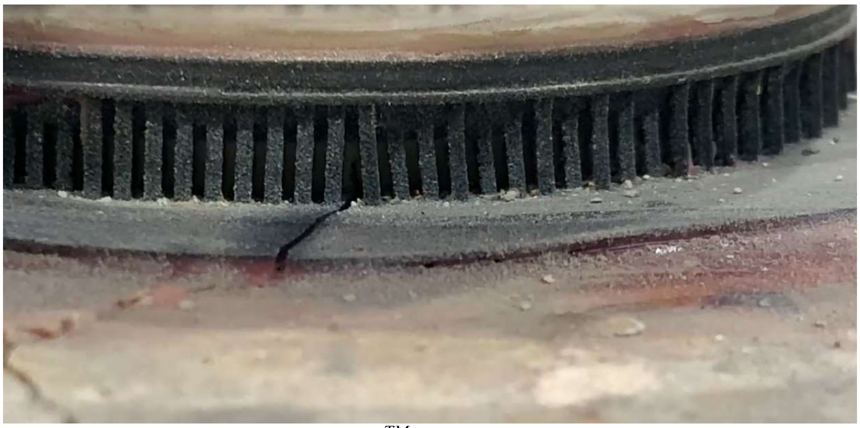


Figure 4. Behavior of C-BLOCK™ in presence of a crack in the concrete.

This fastener is installed using a dedicated tooling in order to ensure the repeatability and traceability of the bonding. The installation tooling and steps are presented in the next paragraph.

C-BLOCK installation - Tooling

The reliability of bonding lays in the repeatability and control of the bonding conditions. In the case of C-BLOCK™, this reliability is guaranteed by an industrial automated installation tool rated for industrial environments and developed especially for this application. This process-controlled tool secures a low variability of mechanical capacity for the fasteners disregarding actual humidity and temperatures. Indeed, the temperature, humidity and pressure are controlled during the bonding operation and this date is gathered by the tooling for traceability purpose. The tooling is presented below:

Figure 5.Left: Installation tooling in its box – Right: installation bell during bonding.

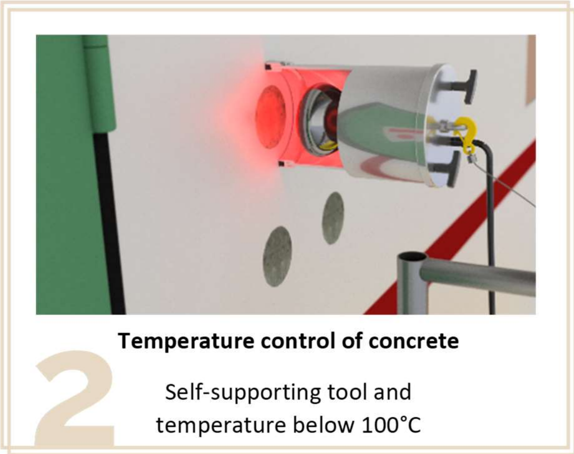
During installation phase, the fastener is positioned inside the bell. The latter is connected to the electrical box (orange box) that controls the whole bonding process. This tool is self-handling which allows the operator to launch a bonding and then move to prepare another bonding while the first one is still ongoing.

C-BLOCK™ installation - Process

The installation of C-BLOCK™ follows 6 steps as follows:

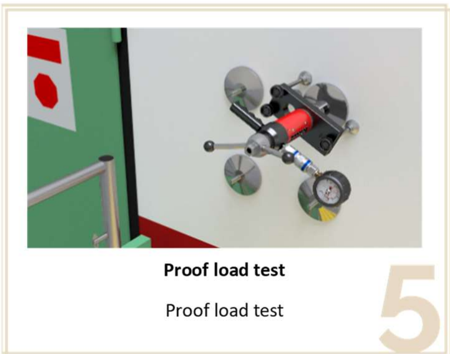
- Surface preparation: this step consist removing the concrete laitance (around 1mm) using a grinding tooling. Then, the grinded surface is cleaned using a solvent wipe.

- Preheating of concrete: using a dedicated automatic tooling the operator increases the temperature of concrete surface in order to accelerate the polymerization of the adhesive.



- Bonding: this step is performed using the tools presented in Figure 5. The operator positions the tooling at the bonding location and launches the bonding. The tooling ensures the bonding parameters are reached (temperature, humidity, pressure) before launching the bonding and stores the bonding parameters during the 20 minutes of bonding cycle.

- Pull test: for each installed C-BLOCK, a proof load test at 500 kg is performed in order to confirm the mechanical resistance of the fastener.



After this step, the fastener can be used to install the outfitting such as a lifting frame as shown below:

Figure 6.Left: C-BLOCK bonding on concrete – Right: lifting frame installed with 4 C-BLOCKs

C-BLOCK mechanical capacities

After more than 5 years of development, the C-BLOCK™ is qualified for applications such as lifting, scaffolding and is planned to be qualified on permanent applications during 2022.

In the absence of an European Assessment Document (EAD) dedicated to C-BLOCK™, COLD PAD and EDF defined a specification of more than 100 tests in order to prove the capacity and reliability of the fastener. This specification is based on existing EADs and EUROCODEs already used for conventional anchoring systems:

- EAD 330499-00-0601 (2017), Bonded fasteners for use in concrete
- EAD 330232-00-0601 (2016), Mechanical fasteners for use in concrete
- EUROCODE EN1992-4, 2018, « Eurocode 2 – Design of concrete structures – Part 4 : design of fastenings for use in concrete »
- EUROCODE EN1992-1-1, 2005, « Eurocode 2 : design of concrete structures - Part 1-1 : general rules and rules for buildings »
- EN1990, 2003, « Eurocode - Basis of structural design »
- EN 206, 2013, “Concrete - Specification, performance, production and conformity”
- EOTA TR048, 2016, "European Organisation For Technical Assessment, Technical Report : Details of tests for post-installed fasteners in concrete"
- EOTA TR049, 2016, "European Organisation For Technical Assessment, Technical Report : Post installed fasteners in concrete under seismic action"

Based on the defined specification, the standard service conditions of C-BLOCK™ are presented in the following table:

Features	C-BLOCK™ Short term	C-BLOCK™ Long term
Expected service life	6 months	Up to 60 years
Environment	Indoor locations	Indoor locations
Humidity	≤ 80%	≤ 60%
Service temperature	5°C ≤ T ≤ 35°C	5°C ≤ T ≤ 25°C
Accidental temperature	40°C	40°C

Radiation exposure	"worker zone" (ie. <2 mSv/h)	"worker zone" (ie. <2 mSv/h)
Min. thickness of concrete substrate	100 mm	100 mm
Min. distance to the edge	100 mm	100 mm
Min. distance between 2 C-BLOCKs	160 mm	160 mm
Seismic resistance	No	Qualification on-going Expected for Q3-2022

Table 1. C-BLOCK™ standard service conditions

The table presents the standard service conditions for C-BLOCK™, however a case by case study shall be performed if a deviation from this framework is noted for a specific application.
As of now, regarding mechanical capacity, C-BLOCK™ is qualified on uncracked C25/30 concrete in tensile and shear strength as follows:

- Tensile design resistance, $N_{rd} = 5.7$ kN
- Shear design resistance, $V_{rd} = 4.6$ kN

The design value is obtained by statistical analysis of the results of the C-BLOCK™ qualification campaign according to the formula :

$$X_{Rd,ucr} = \frac{X_{Rk,25,ucr}}{\gamma_c * \gamma_{inst}}$$

- $X_{Rk,25,ucr}$: Characteristic mechanical capacity (8.6 kN in tensile strength; 7 kN in shear)
- $\gamma_c = 1.5$ safety factor for permanent and transient design cases (see Eurocode 2 part 4)
- $\gamma_{inst} = 1$: safety coefficient taking into account the proof load test

For higher grade concrete, the characteristic tensile and shear strengths are considered the same as for C25/30 concrete (conservative approach).

A VALUE PROPOSITION ON SEVERAL AXES

how to streamline the construction and be 50% quicker ?

Figure 7. Qualitative value proposition

Focusing on the "planning control" feature, **the disruptive value proposition is to avoid the painful and lengthy procedure associated with post-installation dowels and rebar detection**. The non-intrusiveness feature actually allows to dramatically streamline planning up to 50% and therefore provide additional flexibility and cost savings to the operator.

For the analysis, two different scenarios were considered : on the one hand, the standard case for which all the drilling/dowel operations are streamlined with no problem. On the other hand, the worst case scenario for which the rebar is not compatible with the base plate dimension which requires additional operations by the designer and the base plate manufacturer.

In other words, **time savings represent 2 days per outfitting plating support in the standard case** (see Figure 8), and **can be up to 6 days** in the *worst case scenario* (see Figure 9), when the rebar is not compatible with the base plate dimension. This quantitative assessment is derived from a specific business case studied with an HPC contractor. This analysis was performed in a the HPX building (pumping station) of HPC in which 8000 platings are to be installed with 3 anchors per plate (see Figure 10Figure 8). While 73 days were needed for dowels, only 43 days were necessary for **C-Block^{TM}** which **represents a saving of 30 days or a 40% decrease** compared with traditional dowels.

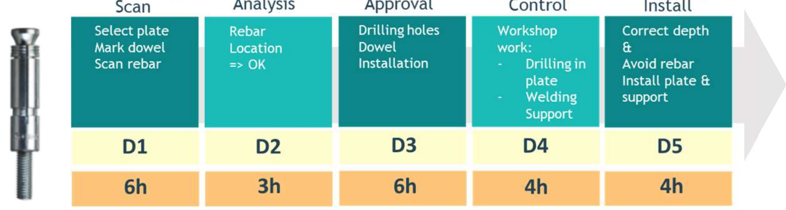


Figure 8. Flowchart & planning of the installation process with traditional dowels (standard case)

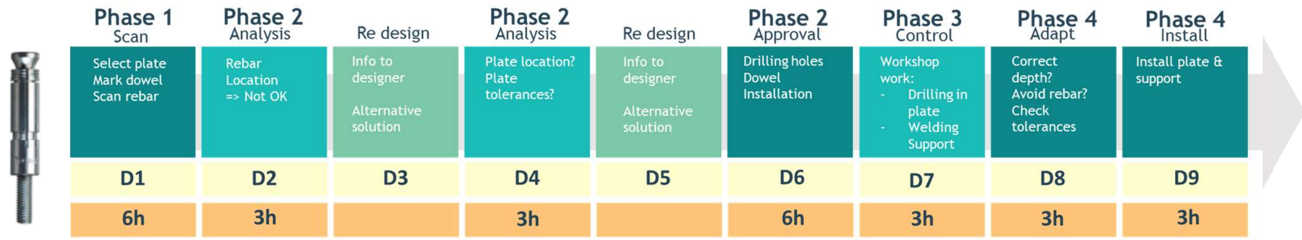


Figure 9. Flowchart & planning of the installation process with traditional dowels (worst case)

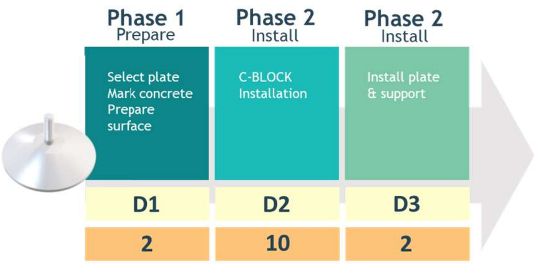


Figure 10. Flowchart & planning of the installation process with non intrusive fasteners

This new methodology is much more straightforward in terms of manpower and interfaces. It uses only one onsite crew, which avoids waiting time between technicians (rebar detection and drilling), which in the end yields to **Enhanced Autonomy** and lower crew sizes. For the worst case scenario, the comparison is even more favourable when base plates need to be redesigned / refabricated !

Temporary outfitting during the construction phase

During the construction of a large power plant like HPC, large quantities of temporary cables and other electrical device need to be installed. Being easily removable before the commissioning with no damage on the base concrete then becomes a stake for an asset intended to operate for 60 years ! C-BLOCK actually exhibits this feature of being removable with neither damage nor structural impact on concrete. The fastener can be hand-sawed through the composite intermediate deformation layer (see Figure 11) within less than one minute. This feature can also be attractive for scaffolding or lifting devices.

Figure 11. removable with no damage on concrete !

Health and Safety benefits

Additional benefits can also be evidenced in terms of health and safety for the onsite personnel. The innovative installation process **REDUCES VIBRATIONS** compared to conventional drilling which is directly correlated to Musculoskeletal disorders like Raynaud's disease, Kohler's disease, or osteoarthritis. As the power tool is both autonomous, self-supported (see Figure 12) and lighter than drilling (4kg against 8kg for drilling), it globally offers an enhanced comfort for the onsite personnel.

In addition there is a massive **NOISE REDUCTION** as the surface preparation only generates 89 dB versus 110 dB for drilling over a much shorter period of time : 1 min for surface preparation versus 5 min for drilling.

Figure 12. self supported power tool – walls & ceilings

CONCLUSION

At the time of this paper writing, 24 out of the 56 nuclear reactors in France are stopped for maintenance mainly due to the delays induced by the 2 years of COVID lockdowns and the increased age of the nuclear power plants. Maintenance on time and on budget becomes a major challenge to be taken up by the nuclear actors and C-BLOCK™ gives them a new tool in their toolbox to streamline the planning and enhance the safety of the maintenance operations.

A first important milestone has been reached with the qualification of the fastener for uncracked concrete. The next milestone within sight is to expand the qualification on cracked concrete, seismic conditions and for higher temperatures and grades of concrete. This expansion shall allow C-BLOCK™ to be usable in more areas inside the nuclear power plants.

After entering the nuclear power plants market, the ambition is now to make C-BLOCK™ available for general civil work. Indeed, COLD PAD is working on a new version of C-BLOCK, with a European certification, a more automatized installation process and at lower cost.

REFERENCES

European Assessment document, EAD 330499-00-0601. (2017). *Bonded fasteners for use in concrete*

European Assessment document, EAD 330232-00-0601. (2016). *Mechanical fasteners for use in concrete*

EUROCODE, EN1992-4, (2018). *« Eurocode 2 – Design of concrete structures – Part 4 : design of fastenings for use in concrete »*

EUROCODE EN1992-1-1, 2005, « Eurocode 2 : design of concrete structures - Part 1-1 : general rules and rules for buildings »

EUROCODE, EN1990, (2003). *« Eurocode - Basis of structural design »*

EN 206, (2013). *"Concrete - Specification, performance, production and conformity"*

EOTA TR048, (2016). *"European Organisation For Technical Assessment, Technical Report : Details of tests for post-installed fasteners in concrete"*

EOTA TR049, (2016). *"European Organisation For Technical Assessment, Technical Report : Post installed fasteners in concrete under seismic action"*