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Thames Tideway East Section – Use of a decisional carbon footprint tool for determining concrete mixes

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ABSTRACT

Thames Tideway Tunnel is the biggest infrastructure project ever undertaken by the UK water industry and has been designed to upgrade London's 150-year-old sewer network. The under-construction 25 km tunnel will intercept wastewater and stormwater and divert them into treatment plants to prevent the release of untreated effluents into River Thames. The East Section consist of six worksites, including 10 km of tunnel, deep shafts, maritime works and structures connected with the existing system.

Even though the project is already an environmentally beneficial project, the Joint Venture aspire to deliver it with the lowest possible contribution to greenhouse gas emissions.

The Joint Venture decided to estimate the carbon footprint of each concrete mix using the internal tool CO_2CRETE IMPACT®. An overall analysis highlighted several opportunities for reducing embodied concrete carbon emissions for both permanent and temporary works. Thereafter, few "reduced carbon" concrete mixes were developed which led to significant savings.

The evaluated carbon footprint of all these mixes have been dispatched on the internal EXEGY® matrix (VINCI's brand for promoting low carbon concrete) and this latter became a useful decisional tool for determining concrete mixes to be used on site based on both properties and CO_2 emissions.

Keywords: Concrete, Carbon footprint, Decisional Tool, Savings

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1 Introduction

The Thames Tideway project is an essential upgrade to the UK's wastewater infrastructure in London, which will bring widespread environmental benefits. Our client also wanted to deliver it with the lowest possible contribution to greenhouse gas emissions. It has, then, challenged the project teams to achieve an 8% reduction in embodied carbon (against a 2016 baseline) with a stretch target of 10%.

Concrete is the most common building material used in the world with circa 14 billion cubic meters of concrete produced every year, representing around 7% of the worldwide carbon footprint.

This data is worrying and indicates that most of the embodied carbon is emitted during the production phase of this material. Cement represents less than 12% of the concrete in weight but up to 85% of carbon footprint. This arises from the production process where limestone and clay are calcinated at over 1400˚C to produce the clinker (roughly 1 tonne of carbon dioxide for 1 tonne of clinker produced). Two thirds of these emissions being due to the calcination process while the other third is due to the heating in the rotating kiln.

Based on this statement, CVB Joint-Venture decided to estimate CO_2 emissions of all concrete mixes used on East Section of Thames Tideway project and to carry out an overall analysis for investigating opportunities to reduce the carbon footprint.

2 Carbon footprint of each concrete mix

Carbon footprint of each concrete mix used across the six sites has been estimated, taking into account the volume of concrete poured, the composition of each mix and the characteristics of the components (see Figure 1). For each component, was considered the distance from the quarry or factory to the batching plant, the onward journey to the construction site as well as the transport method and type of mixer truck used. As a matter of fact, a "scope 3" (as per Green House Gas Protocol elaborated by the *World Business Council for Sustainable Development (WBCSD) and the World Resources Institute* (WRI)) level carbon footprint analysis has been carried out.

Figure 1: Considering CO_2 emissions from quarry / cement factory to the batching plant / site.

The calculation of the greenhouse gas emissions due to the concrete was performed using CO_2CRETE IMPACT® - an evaluation tool developed by the Technical Department of VINCI Construction Grands Projets in collaboration with VINCI Construction France and Eurovia. CO_2CRETE IMPACT® database was benchmarked to ICE Database [1] and estimated CO_2 emissions were considered similar.

Thus, the carbon footprint of all concrete mixes used on the Tideway East project was quantified considering greenhouse gas emissions due to the production of each concrete components, the concrete mix design, the transportation before and after concrete batching as well as the geographical location of the construction site in relation to the ready-mix suppliers.

As there is no real agreement on a class system for low carbon concrete, concrete has been classified according to an in-house matrix called Exegy® matrix which was developed at VINCI Construction to implement its voluntary attempt to decrease CO_2 emission on each construction site [2]. The Exegy® matrix (see Figure 7) defines 4 classes of concrete based on their compressive strengths (cylinders) and carbon footprints.

3 CO_2 emissions of concrete mixes

The Figure 3 highlights CO_2 emissions of each concrete mixes poured on site for permanent works structures. It is to be noted that concrete mixes are organized from lowest strength class (C12/15; Mixes E01) to highest strength class (C50/60; Mixes E08 and E10).When considering volumes of concrete poured on site from the start of the project in 2017 until August 2022, it could be highlighted that roughly 50% of the permanent works structures have been poured with low-carbon concrete mixes – 73,000 m^3 out of a total 150,000 m^3.This analysis is biased by the precast segments which required a very high early strength gain for casting twice a day (15 MPa after 9 hours). The same analysis considering only "poured in-situ concrete" increase the percentage of low-carbon mixes for permanent structures to 96%.

The Figure 4 highlights CO_2 emissions of each concrete mixes poured on site for temporary works structures. It is to be noted that concrete mixes are organized from lowest strength class (C12/15) to highest strength class (C50/60). When considering volumes of concrete poured on site from the start of the project in 2017 until August 2022, it could be highlighted that only 45% of the temporary works structures have been poured with low-carbon concrete mixes – 8,300 m^3 out of a total 19,000 m^3.

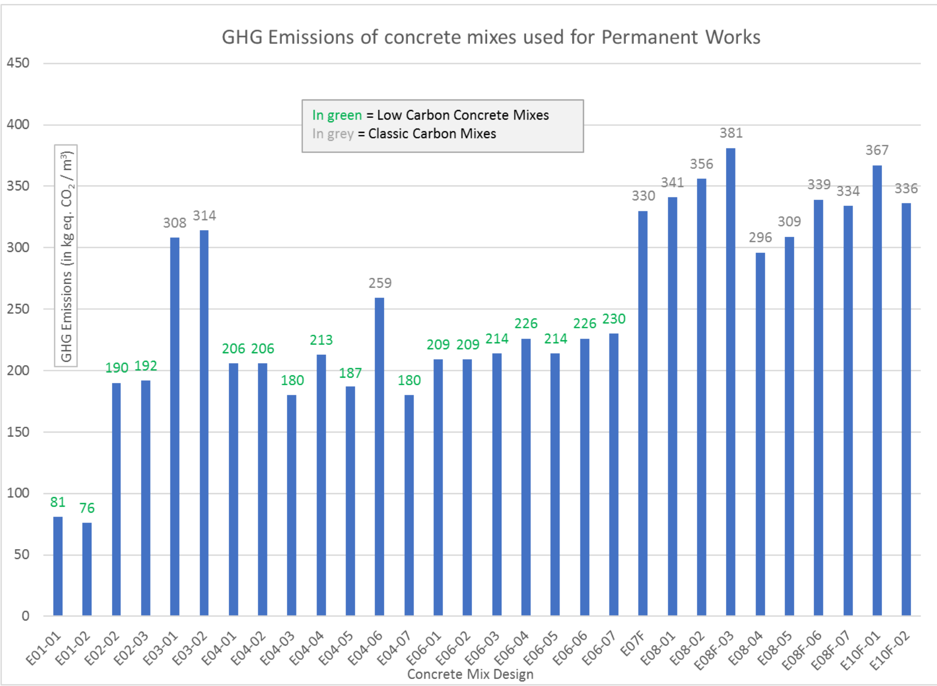

Figure 2: CO_2 emissions of each concrete mixes poured for permanent works structures.

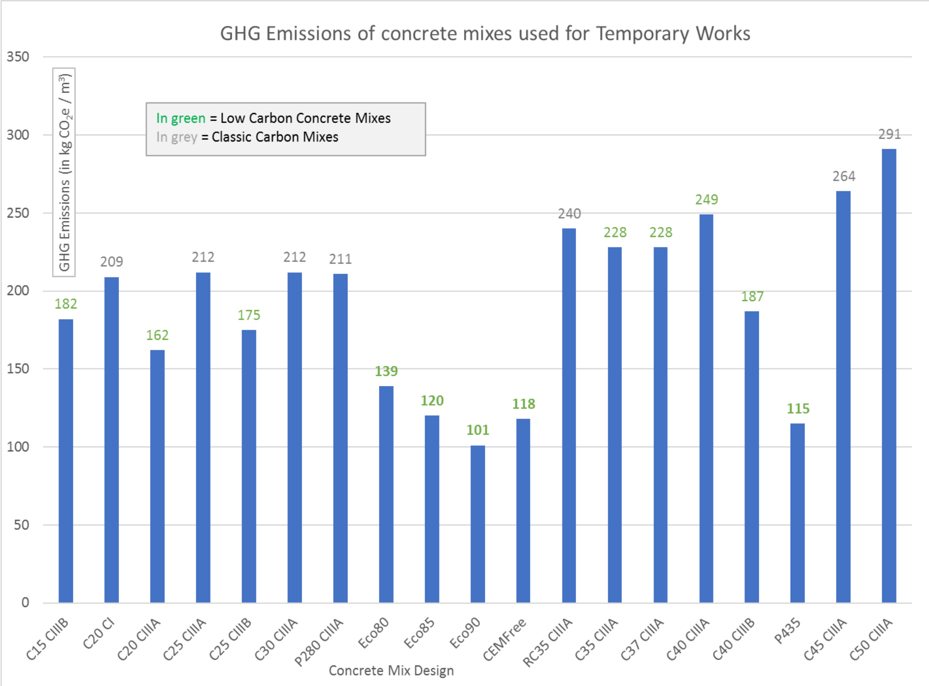

Figure 3: CO_2 emissions of each concrete mixes poured for temporary works structures.

4 Reduced carbon concrete mixes and corresponding savings

Several "reduced carbon" concrete mixes were developed for reducing the carbon performance (see Figure 5).

- For the low-heat Mix "E04", the proportion of GGBS was increased from 67% to 73%, reducing embodied carbon by 26 kg CO_2e/m^3. Overall, 6000 m^3 of this concrete had been poured up to the end of August 2022, saving at least 150 t CO_2e.
- For the abrasion-resistant Mix "E08", the proportion of GBBS was increased from 40% to 50%, the maximum permitted for this kind of concrete, reducing embodied carbon by 46 kg CO_2e/m^3. During the same period, 450 m^3 of concrete was poured, representing a carbon reduction of more than 40 t CO_2e and this latter number will increase towards time as there are still hundreds of cubic meters of concrete to pour with this reduced carbon concrete mix.
- For the Tunnel Secondary Linings Mix "E10", considering a Marine sand dredged at Dagenham instead of a sand imported from Denmark reduce the CO_2 emissions by circa 30 kg CO_2e/m^3 which will lead to a saving of more than 1,350 t CO_2e for the 45,000 m^3 of concrete to be poured.

After having analysed the CO_2 emissions of concrete mixes for temporary works structures, it was decided to design a range of few very-low to ultra-low-carbon mixes made of 80%, 85% and 90% GGBS. These "reduced carbon" concrete mixes have replaced C20/25 to C25/30 concrete mixes enabling a reduction of CO_2 emissions by at least 70 kg CO_2e/m^3 (see Figure 6).

The project team also developed an ultra-low carbon mix for reducing the carbon associated with C30/37 to C40/50 mixes, to meet a higher strength requirement of 45-50MPa. This "reduced carbon" concrete mix represents a saving of at least 100 kg CO_2e/m^3 compared to conventional ones (see Figure 6). Pouring 280 m^3 for the batching plant foundations saved approximately 20 t CO_2e.

Considering couple of "high strength" ultra-low carbon concrete mixes at the start of the project could have reduced the carbon footprint of Temporary Works Structures by 1000 to 1200 t CO_2e.

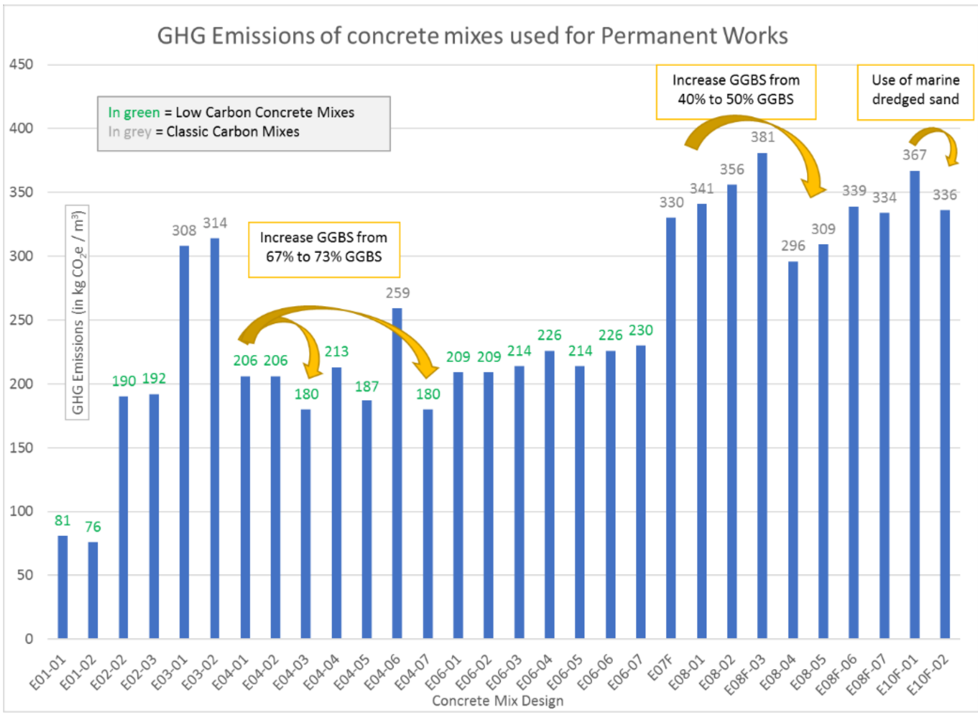

Figure 4: Reduced carbon concrete mixes developed for permanent works structures.

Note: Steel fibres and rebars are not considered in these estimated CO_2 emissions

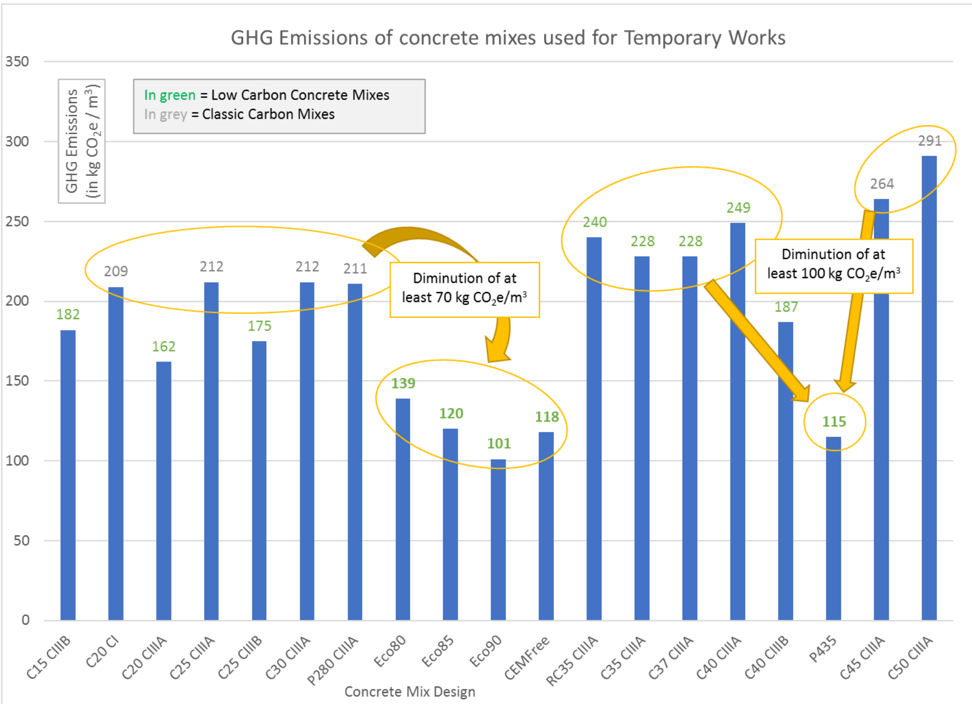

Figure 5: Reduced carbon concrete mixes developed for temporary works structures.

5 Decisional carbon footprint tool

Each concrete mix used on Tideway East have been distributed on the Exegy® matrix (see Fig. 7 for Permanent Works structures and to Fig. 7 for Temporary Works structures) considering both CO2 emissions and strength class of the concrete mix. The two below charts were thus communicated internally within the joint venture and are now used as a decisional tool for determining the most “environmentally friendly” concrete mix for each site application.

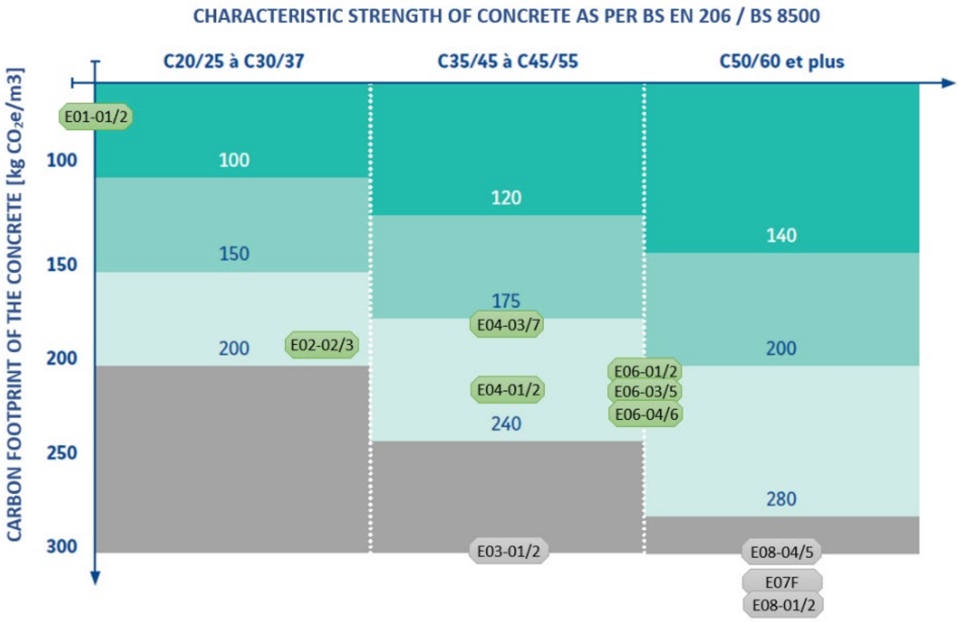

Figure 6: Decisional tool for Permanent Works Structures

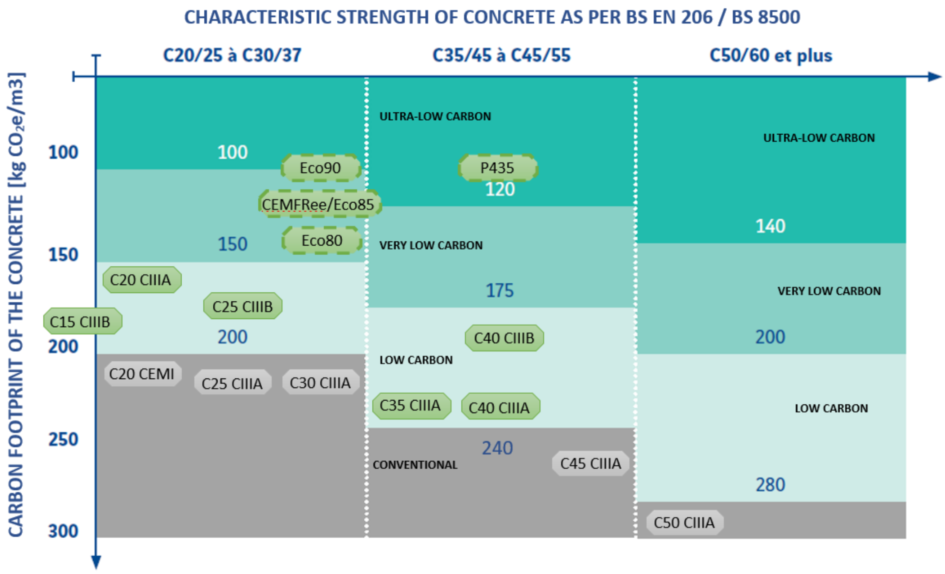

Figure 7: Decisional tool for Temporary Works Structures

In addition, it has been decided to benchmark the Exegy® matrix and thus the decisional tool used on Tideway East comparing VINCI’s range of Exegy® solutions to the thresholds published in the ICE Low Carbon Concrete Roadmap [3].

As highlighted in Figure 9, the Exegy® matrix looks slightly more challenging in term of CO_2 emissions than the Low Carbon Concrete Guidance Recommendations specified in the ICE Roadmap and more especially for the high strength concrete mixes (C40/50 and above).

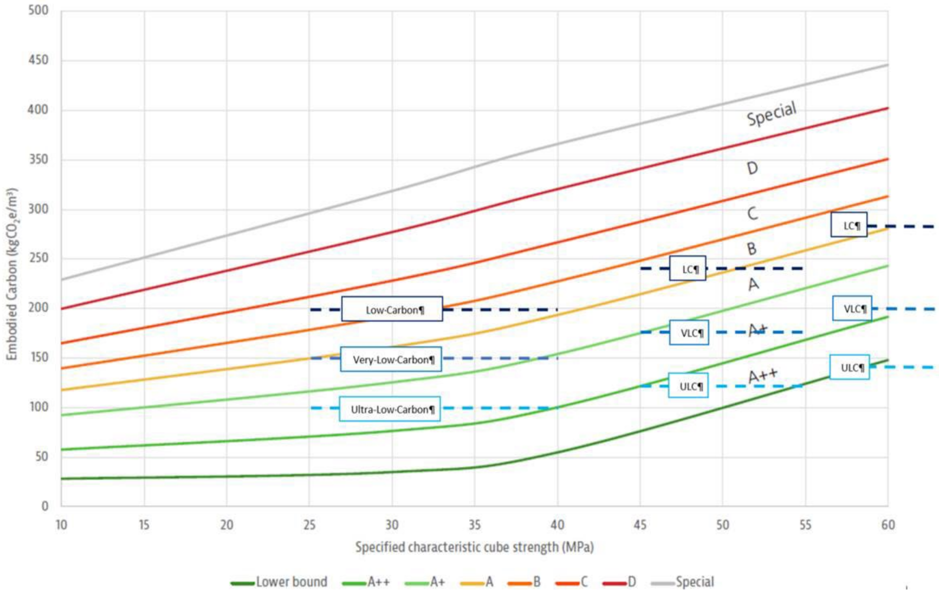

Figure 8: Benchmark of the Exegy® matrix with the Figure 1.2 of the ICE Roadmap.

6 CONCLUSIONS

This analysis has highlighted many outstanding points which shall be considered for limiting CO_2 emissions for future projects:

- 50% of permanent works structures have been poured with low carbon concrete mixes and up to 96% when considering concrete poured on site (with exception of the precast segments). Using low carbon concrete in case of high early age strength requirements can still be a blocking point however there are technical solutions which could be implemented for getting rid of it: estimation of the in-situ strength, hot concrete, heat curing, etc
- Only 45% of low carbon concrete mixes poured for temporary works structures. As there are less early age strength requirements for temporary works structures, this shall be significantly improved by developing a range of low carbon concrete mixes from the start of projects.
- Use of a decisional tool gave the opportunity to the site teams to consider low / reduced carbon concrete mixes.

In this specific analysis Exegy® is limited to the technical standard matrix however Exegy® brand also includes the Engineering know-how from design to execution to define the most optimized concrete (technical and environmental performance at competitive cost) and to adapt methods and equipment to pour these Exegy® concrete solutions on site in partnership with our ready mixed producers.

VINCI's commitment to reach 90% low carbon concrete by 2030 is technically feasible at no additional cost. However, analyzing carbon footprint of concrete as it has been done on Tideway East should be undertaken at every project to reduce carbon footprint of our concrete infrastructures.

Acknowledgement

CVB would like to take the opportunity to thank CVB's parent companies for pushing more environmentally friendly solutions.

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2. Boumaaza M, Linger L, Boutillon L, Paul-Dauphin B (2021) – "Implementation of Low Carbon Concrete: allowance and constraints set by international main standards. A review"
3. ICE Low Carbon Concrete Roadmap, 2022.

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