Environmental Product Declaration

Precast concrete ring

Brenner Base Tunnel

Ghella Spa

THE INTERNATIONAL EPD® SYSTEM

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1. Introduction

The Brenner Base Tunnel (BBT) will extend for 55 km between the stations of Fortezza (BZ) and Innsbruck (Austria), where it will be connected to the existing underground ring road, reaching an overall length of 64 km: once completed, it will become the longest underground railway tunnel in the world. The Brenner Base Tunnel is part of the larger upgrading project of the High-Speed railway axis Verona – Munich.

The "Mules 2-3" construction lot represents the main part of the BBT line on the Italian side and extends to the Austrian border. The lot will see the construction of two railway tunnels and an exploratory tunnel, as well as an access tunnel. The tunnels will be built either using three Double Shield Tunnel Boring Machines (TBM) and with a traditional excavation method, using “Drill and Blast”method or demolition hammers, according to the excavation cross-section.

The company

Founded in 1894, Ghella is a leading company in the construction of major infrastructure projects worldwide. Specialized in underground works, the company is known worldwide for its expertise in the use of Tunnel Boring Machines (TBM) and is active in the construction of infrastructure projects such as subways, railways, motorways and hydraulic works. The company's headquarters are located in Rome, but the largest production is concentrated abroad mainly in Oceania, the Americas, Europe and the Far East.

Proper management of environmental issues has always been at the heart of Ghella's *modus operandi* and is formalized through the adoption of an Integrated Management System, whose environmental component is certified in accordance with the international standard ISO 14001: 2015.

The product

The construction of tunnels through mechanized excavation and internal lining with prefabricated concrete segments reduces construction times and increases the quality of the infrastructure. The use of TBMs allows the three phases excavation, disposal of waste material and positioning of prefabricated concrete rings for the internal lining of the tunnel to happen in one continuous process. These rings are made up of segments, which are prefabricated in factories outside the excavation site and then positioned on the tunnel walls through the TBM.

Ghella decided to perform an LCA study to evaluate the environmental performance of 1 m^3 of "CE ring" used in the realization of the Exploratory Tunnel CE of the Brenner Base Tunnel. The LCA study is used as a tool to obtain a “cradle to gate” EPD certification.

Each CE ring is made up of:

- 6 prefabricated segments (5 + 1 keystone), equipped with gaskets for hydraulic sealing, guide bars for correct positioning and inserts for the mounting process;
- 2 prefabricated segments used as a support base for the realization of the final plan (base segment 1 and base segment 2).

The specifications of the CE ring and the related design are shown respectively in Table 1 and Figure 1. The mix design of 1 m^3 concrete is shown in Table 2. Table 3 contains the materials used to make 1 m^3 of CE ring.

SEGMENTS	CONCRETE (mc)	Fe (kg)	Fe (Kg)/mc
Segment A (key)	0,54	118,02	218,56
Segment B	1,62	289,94	178,98
Segment C	1,62	289,94	178,98
Segment D	1,62	291,96	180,22
Segment E	1,62	289,94	178,98
Segment F	1,62	289,94	178,98
Lower base	1,11	111,82	100,74
Upper base	2,60	386,52	148,66
Ring CE + base	**12,35**	**2.068,08**	**167,46**

Table 1: Specifications of the CE ring.

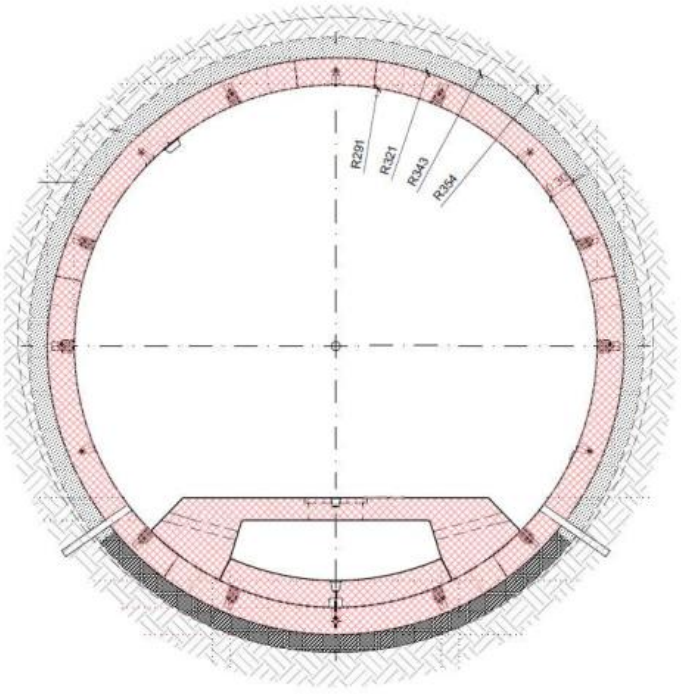

Figure 1: CE ring.

Materials	Concrete (mc)
Fine aggregate 0/4	760 kg/mc
Big aggregate 4/8	300 kg/mc
Big aggregate 8/16	400 kg/mc
Big aggregate 16/22	420 kg/mc
Cement	360 kg/mc
Ash	72 kg/mc
Additive	3.6 kg/mc
Free water	142 l/mc
Teoric ratio A/C	0,395
Teoric ratio a/legan.equ.	0,365

Table 2: Mix design of concrete.

COMPONENTS	MATERIAL	kg	%
Concrete	Concrete	2446	93.44%
Steel B450C	Steel	167.5	6.40%
Injection insert T142-BBT	PP	2.15	0.08%
Dowel BIBLOCK	PA+FG (30%)	0.97	0.04%
Bars	Recycled PVC	0.41	0.02%
Welding wire	Steel/Mn/Si/Cu/C/Cr/Ni/S/Mo/Al/Sn	0.38	0.01%
Disarmante Pieri LM 100	Mineral oil	0.30	0.01%
External gasket UG66B	EPDM	0.02	0.00%
Adhesive Elastofip primer HT	Chemical compound	0.01	0.00%
Total		**2617.74**	**100%**

Table 3: Weights of the components of 1m3 of CE precast concrete ring.

The production process is explained in the flow chart shown in Figure 2:

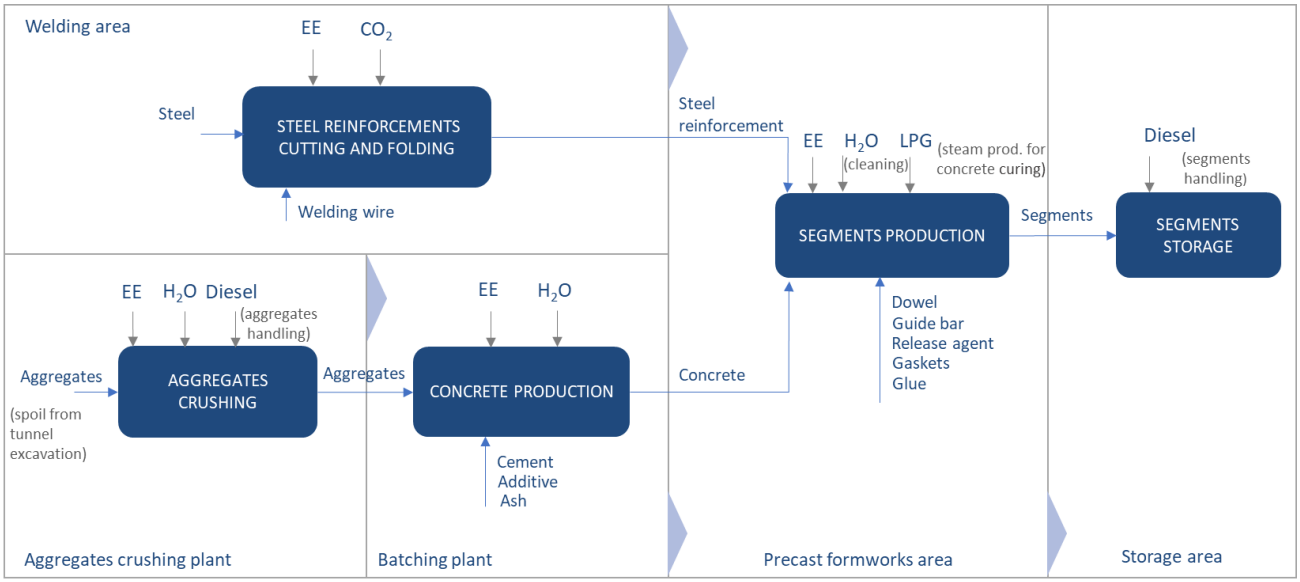

Figure 2: Flow chart related to the production of segments, in the segment factory placed in "Mules 2-3"Lot.

2. Environmental information

Declared Unit

The declared unit is represented by 1 m^3 of CE precast concrete ring.

System boundaries

This LCA study is a "from cradle to gate" analysis, therefore the boundaries of the LCA system of the precast concrete CE ring include the production of raw materials, their transport, the production phase of semi-finished products, components and segments.

Table 4 shows the phases of the product life cycle and the information modules considered for the evaluation of construction products according to the UNI EN 15804 standard.

BUILDING LIFE CYCLE INFORMATION															ADDITIONAL INFORMATION
PRODUCT STAGE			CONTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFIT AND LOAD
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw materials supply	Transport	Manifacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	refurbishment	operational energy use	operational water use	de-construction / demolition	Transport	Waste processing	Disposal	reuse, recovery or recycling
X	X	X	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table 4: Information modules for the evaluation of construction products according to the EN15804.

According to EN 15804 the end of life (modules C1-C4) and the additional information of module D have not been included as the following conditions are valid:

- the product is physically integrated with other products during installation, so they cannot be physically separated from them at the end of life;
- the product is no longer identifiable at the end of life as a result of physical or chemical transformation process;
- the product does not contain biogenic carbon.

Upstream processes (Figure 2) include the supplying of raw materials such as steel, cement, ash, additives and inserts; the extraction of aggregates and the related production of aggregates.

Core processes include transport to the gate of the segment factory and any other internal transport, production of semi-finished products such as concrete, manufacture of segments and their transport to the storage site.

The upstream and core processes include waste disposal treatments generated during the production process.

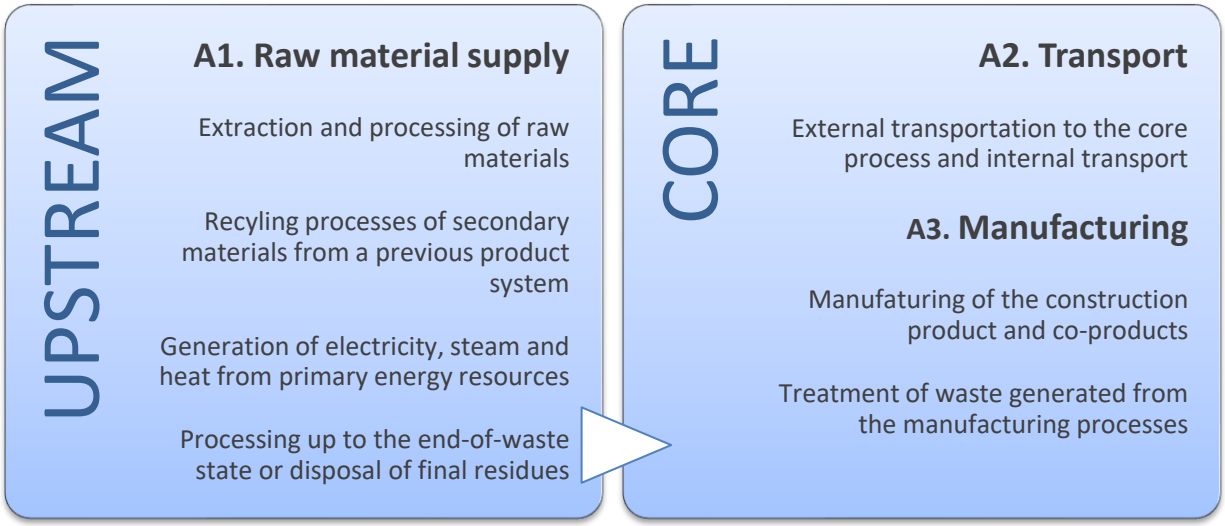

Figure 3: LCA system boundaries.

Time boundaries

Primary data originate from Ghella and refers to the period November 2019 - January 2020. The choice of a three-month period is linked to non-constant production based on the supply of aggregates, therefore on the speed of advancement of the TBM in the tunnel. Secondary data comes from the ecoinvent v3.6 database, published in 2019.

Geographical boundaries

The production of aggregates takes place inside a crushing plant conducted by the subcontractor Adinolfi, while the production of segments takes place inside a segment factory, by the subcontractor Isocell. Both plants are located on site, at the "Mules 2-3" construction lot.

The components and the precast concrete ring of the analyzed system are produced and installed in Italy, so the study refers to the Italian situation.

Boundaries in the life cycle

As indicated in the PCR, the following processes are excluded in the LCA: the construction of company buildings; the production of work equipment and other capital goods; the activities of the staff. Infrastructures, when present, such as processes deriving from the ecoinvent database have not been excluded.

Data quality

Both primary and secondary data are used in this study. Primary data are collected and provided by Ghella through the compilation of questionnaires and direct communications; when primary data are not available, secondary data are used.

The life cycle analysis must consider at least 95% of the total mass and energy flows. Proxy data can be used in case data lack exists, as long as their contribution in the environmental performance assessment does not exceed 10% for each main impact category.

Environmental impact indicators

The information obtained from the inventory analysis is aggregated according to the effects related to the various environmental issues. To evaluate the environmental performance of the product, the EN 15804 + A2 method developed by PRé in SimaPro was used on the basis of the UNI EN 15804 standard.

PCR 2019:14 and UNI EN 15804 standard establish four indicators for climate impact (GWP-GHG): GWP (total) which includes all greenhouse gases; GWP (fossil fuels); GWP (biogenic carbon) which includes the emissions and absorption of biogenic carbon dioxide and biogenic carbon stored in the product; GWP (land use).

Allocation rules

Raw materials and production processes are included for virgin resources. No allocation is made for materials subject to recycling. The recycling process is included for the input of recycled resources. Outputs subject to recycling are considered inputs for the next life cycle.

End-of-life allocation criteria were applied to the following two materials:

- ash is a product from coal incineration, therefore it represents a waste that is recycled in a different life cycle;
- recycled PVC, for which no material input is considered but only energy for the processes before being reused.

The consumption of electricity, heat, water, diesel and the production of waste produced by the entire plant in the reference period was allocated according to the criterion of the volume of CE precast concrete ring produced in the same period.

Inventory

This LCA study is based on primary data for the fundamental aspects of the study, such as the consumption of the Isocell plant and the weight of the main components of the CE precast concrete ring.

The energy mix from the ecoinvent database “Electricity, medium voltage {IT} | market for|“ has been modified to make it more representative to the Italian situation, modeling the individual sources on the basis of the supply mix declared in the invoice. The Italian energy sources derive from the ecoinvent database.

The process “Transport, freight, lorry 16-32 metric ton, EURO5 (RER)” was chosen to indicate the means used by suppliers, based on the information communicated by Ghella.

For all steel processes for which primary data were not available, representative data originating from EPD declarations of Pittini, Feralpi Group, Ferriera Valsabbia, and Industrie Riunite Odolesi, were used.

For all processes for which primary were not available, such as the production of raw materials of inserts and related manufacturing processes, generic data originating from the ecoinvent v3.6 database, allocation cut-off by classification, were used. The ecoinvent database is available in the SimaPro v9.1 software used for the calculations.

As required by the PCR 2019:14 the use of proxy data has been limited and their contribution does not exceed 10% of the overall impact of the impact categories. All material inputs of the production process were evaluated.

3. Environmental impact indicators

Table 5 shows the environmental impact indicators of the life cycle of 1 m^3 of CE precast concrete ring, as indicated by PCR 2019:14 v1.1, UNI EN 15804 and UNI EN 16757 standards.

The UNI EN 15804 + A2 method consists of impact categories (global warming - fossil fuels, global warming - biogenic carbon, global warming - land use, global warming - total, ozone layer depletion, photochemical oxidation , acidification, eutrophication - fresh water, eutrophication - marine, eutrophication - terrestrial, abiotic depletion, abiotic depletion - fossil fuels, use of water); additional indicators (particulate matter, ionizing radiation, freshwater ecotoxicity, human toxicity - non-cancer, human toxicity - cancer, land use); use of resources (renewable, non-renewable, secondary, fresh water consumption); waste and recycled materials.

The indicators are divided into the contribution of the processes to the different product phases: phase A1, relating to the supply of raw materials (upstream processes), and to phases A2 and A3 (core processes), relating respectively to the transport of raw materials to the production site and production process.

1 m³ of CE precast concrete ring		Unit	Total	Upstream	Core	
				A1	A2	A3
Environmental impact categories	Climate change	kg CO_2eq	385	353	14	17
	- Climate change - Fossil	kg CO_2eq	381	350	14	17
	- Climate change - Biogenic	kg CO_2eq	3.80	3.53	0.01	0.26
	- Climate change - Land Use	kg CO_2eq	0.060	0.054	0.004	0.002
	Ozone depletion	kg CFC 11 eq	0.015	0.015	0.000	0.000
	Acidification	mol H^+ eq	1.08	0.91	0.06	0.11
	Eutrophication, freshwater	kg P eq	0.094	0.091	0.001	0.002
	Eutrophication, marine	kg N eq	0.221	0.176	0.018	0.026
	Eutrophication, terrestrial	mol N eq	2.46	1.97	0.20	0.29
	Photohemical ozone formation	kg NMVOC eq	0.761	0.610	0.064	0.087
	Resources use, minerals and metals	kg Sb eq	0.017	0.017	0.000	0.000
	Resources use, fossils	MJ	3630	2922	223	485
	Water use	m^3 deprived	50.8	47.8	0.7	2.3
Additional indicators	Particulate matter	Disease incidence	0.000	0.000	0.000	0.000
	Ionising radiation	kBq U235 eq	15.9	12.6	1.1	2.2
	Ecotoxicity, freshwater	CTUe	2232	1777	177	277
	Human toxicity, cancer	CTUh	0.000	0.000	0.000	0.000
	Human toxicity, non cancer	CTUh	0.000	0.000	0.000	0.000
	Land use	Pt	793	477	255	61
Use of resources	Energy resources, renewable	MJ	255	241	3	10
	Raw materials resources, renewable	MJ	0.000	0.000	0.000	0.000
	Total resources, renewable	MJ	255	241	3	10
	Energy resources, non renewable	MJ	1547	1547	0	0
	Raw materials resources, non renewable	MJ	2375	1621	237	518
	Total resources, non renewable	MJ	3922	3168	237	518
	Use of secondary material	kg	2989	2989	0	0
	Total amount of water	m^3	6.15	6.04	0.05	0.06
Waste	Hazardous waste	kg	4.21	4.17	0.01	0.03
	Radioactive waste	kg	0.001	0.001	0.000	0.000
	Non hazardous waste	kg	14086	3553	19	10514
	Materials for recycling	kg	11232	719	0	10513

Table 5: Characterization results of 1 m3 of CE precast concrete ring.

4. Contact and other information

Ghella contacts

The LCA and EPD have been produced by Ghella in collaboration with 2B Srl (www.to-be.it). The company references are:

Francesca Paracini

Ghella Spa, the EPD owner has the sole ownership, liability and responsibility of the EPD

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ISO standard ISO 21930 and CEN standard EN 15804 serves as the core Product Category Rules (PCR)
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PCR review was conducted by: The Technical Committee of the International EPD® System. Review chair: Claudia A. Peña, University of Concepción, Chile. The review panel may be contacted via the Secretariat www.environdec.com/contact.
Independent third-party verification of the declaration and data, according to ISO 14025:2006: ▪ External □ Internal covering □ EPD process certification ▪ EPD verification
Third party verifier: CSQA Certificazioni SRL *In case of certification bodies:* Accredited by: Accredia *In case of individual verifiers:* Approved by: The International EPD® System Technical Committee, supported by the Secretariat
Procedure for follow-up during EPD validity involves third party verifier: ▪ Yes □ No

According to ISO 14025, EPDs within the same product category but from different programmes may not be comparable.

EPDs of construction products may not be comparable if they do not comply with EN 15804.

5. Bibliography

- Report LCA di un Anello prefabbricato in calcestruzzo, Galleria di Base del Brennero, 2020. 2B e Ghella.
- PCR 2019:14 v1.1. "Construction products", Product Category Rules (PCR) for preparing an environmental product declaration (EPD) for construction products and construction services, the Swedish Environmental Management Council (www.environdec.com).
- c-PCR-003 "Concrete and concrete elements", Complementary Product Category Rules to PCR 2019:14 for preparing an environmental product declaration (EPD) for construction products and construction services, the Swedish Environmental Management Council (www.environdec.com).
- UNI EN 15804:2012+A2:2019, 2019: Sostenibilità delle costruzioni - Dichiarazioni ambientali di prodotto - Regole quadro di sviluppo per categoria di prodotto, Ente Nazionale Italiano di Unificazione, settembre 2019.
- UNI EN 16757:2017: Sostenibilità delle costruzioni - Dichiarazioni ambientali di prodotto - norme di categoria di prodotto per cemento ed elementi in calcestruzzo, Ente Nazionale Italiano di Unificazione, giugno 2017.
- ISO 14025:2006. Environmental labels and declarations, type 3 environmental declarations, principles and procedures (www.iso.org).
- ISO 14040/14044:2006. ISO series on Life Cycle Assessment (Valutazione del ciclo di vita), UNI EN ISO 14040:2006 e 14044:2006 (www.iso.org).
- IEC, 2019. International EPD Cooperation (IEC), General Programme Instructions for Environmental Product Declaration EPD, Version 3.01, dated 2017-09-18. Swedish Environmental Management Council (www.environdec.com).
- Ecoinvent, 2019. Swiss Centre for Life Cycle Assessment, v3.6 (www.ecoinvent.ch).
- PRé Consultants, 2020. Software SimaPro versione 9.1 (www.pre.nl).
- Mix energetico, Repower (www.repower.com/it/informazioni-e-servizi/mix-energetico/)
- Ghella, www.ghella.com.
- Isocell, www.isocellitalia.it.
- Feralpi Group, 2017. Environmental Product Declaration, Steel products: strectched coil electrowelded mesh cold rolled; Certification n. S-P-01025, International EPD, 05/05/2017.
- Feralpi Group, 2019. Environmental Product Declaration, Hot-drawn reinforcing steel for concrete in bars and coils; Certification n. S-P-00256, International EPD, 18/10/2019.
- Ferrieri Valsabbia, 2018. Environmental Product Declaration, Steel deformed bars for concrete reinforcements; Certification n. S-P-00253, International EPD, 16/11/2018.
- Pittini, 2019. Environmental Product Declaration, Acciai laminati a caldo; Codice di registrazione ECO EPD 00001093, EPD Italy, 11/12/2019.
- Industrie Riunite Odolesi, 2017. Environmental Product Declaration, Environmental Product Declaration for hot-drawn reinforcing steel for concrete in bars; Codice di registrazione ECO EPD 00000596, EPD Italy, 31/03/2017.
- BBT, Galleria di Base del Brennero (https://www.bbt-se.com/it/).