

Environmental Product Declaration



CONCRETE
ALBERTA

Concrete Alberta Member Industry-Wide EPD for
READY-MIXED CONCRETE



ASTM International Certified Environmental Product Declaration

Declared Product	This Environmental Product Declaration (EPD) covers concrete mixes produced by Concrete Alberta members.	
Declaration Owner	Concrete Alberta 4944 Roper Rd NW Edmonton, AB T6B 3T7 Phone: 780-436-5645 Website: www.concretealberta.ca	
Program Operator	ASTM International 100 Bar Harbor Drive West Conshohocken, PA 19428-2959, USA Website: www.astm.org	
LCA and EPD Developer	Athena Sustainable Materials Institute 280 Albert Street, Suite 404 Ottawa, ON K1P 5G8, Canada Website: www.athenasmi.org	
Core PCR	ISO 21930:2017 Sustainability in Building Construction - Environmental Declaration of Building Products	
Sub-category PCR	NSF International Product Category Rule (PCR) for Concrete Version 2.1 (August 2021), Verified by Thomas P. Gloria, Ph.D., Industrial Ecology Consultants	
Independent LCA Reviewer and EPD Verifier	Independent verification of the declaration and data, according to ISO 21930:2017 and ISO 14025:2006 <input type="checkbox"/> Internal <input checked="" type="checkbox"/> External	
	Thomas P. Gloria, Ph.D., Industrial Ecology Consultants, ASTM International	
Date of Issue	July 27, 2022	
Period of Validity	5 Years – Valid until July 27, 2027	
EPD Number	EPD 346	
The declared product meets the following product specifications: <ul style="list-style-type: none"> • ACI 211: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete • CSA A3000: Cementitious materials compendium • CSA A23.1/A23.2 Concrete materials and methods of concrete construction/Test methods and standard practices for concrete • ACI 318: Building Code Requirements for Structural Concrete • ASTM C94 Standard Specification for Ready-Mixed Concrete • CSI MasterFormat Division 03-30-00: Cast-in-Place Concrete • UNSPSC Code 30111500: Ready Mix 		Disclaimer: EPDs are comparable only if they comply with this document, use the same sub-category PCR where applicable, include all relevant information modules and are based on equivalent scenarios with respect to the context of construction works. The ready mixed concrete products represented in this EPD are comprised of (in order of greatest mass per mix): natural and crushed aggregates, Portland cement, fly ash, batch water, and admixtures.

Methodology of Underlying LCA

Declared Unit

The declared unit is 1 cubic metre of ready mixed concrete. Products covered by this EPD satisfy general purpose concrete as used in residential, commercial and public works applications in Alberta. Key product variables include:

- **28-day strength** – Different compressive strengths were considered;
- **Fly Ash** – Varies between 0% and 20%;
- **Admixture use** – The use of air-entraining, water reducing, and high range water reducing admixture varies;
- **Aggregate use** – The use of crushed coarse, crushed fine, natural coarse, and natural fine aggregates varies.

Product (mix design) components include the following: Portland cement (GU), Portland limestone cement (GUL), fly ash, natural and crushed aggregates, admixtures and batch water.

Scope

The modeled concrete mixes included benchmarks for each strength class. This EPD is intended for use in Business to Business (B-to-B) communication. This EPD can only be used and referenced by members of Concrete Alberta. The scope of this EPD is cradle-to-gate and considers the following life cycle stages (Figure 1):

- **A1 - Raw Material Supply:** Includes all upstream processes related to extraction, handling, and processing of the raw materials and intermediate component products as well as fuels used in the production of concrete. Component products include cement, supplementary cementitious materials, aggregate (coarse and fine), water, admixtures and other materials or chemicals used in concrete mixtures.
- **A2 - Transportation:** Accounts for the transportation of all input materials and fuels from the supplier to the gate of the concrete plant.
- **A3 - Manufacturing (Core Processes):** Includes all core processes and the energy and water used to store, move, batch and mix the concrete and operate the concrete plant as well as the transportation and processing of wastes from these core processes.

Building Life Cycle Information Modules															
Product stage			Construction Process stage		Use stage							End-of-life stage			
Raw Material supply	Transport	Manufacturing	Transport	Construction/Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	De-Construction/ Demolition	Transport	Waste processing	Disposal

Figure 1: Life cycle stage schematic – alpha-numeric designations as per NSF PCR 2021

Description of Product

This EPD presents results for the range of products that are available across Alberta. For each specified mix, variations were developed based on the use of GU/HS and GUL/HSL cement as well as different SCM replacement levels. For each mix, a “baseline” mix was developed that represents the average product mix within Alberta. The mixes presented in this EPD utilize the following naming convention:

Mix Name: Identify the 28-day specified compressive strength of the proposed product by type of cement unless otherwise specified. Portland cement, also known as Type I or General Use cement is labeled as “GU” or Type V or High Sulphate Resistant Cement is labelled as “HS”. Portland limestone cement, also known as Type IL or General Use Limestone cement is labeled as “GUL” or Type IL-HS or High Sulphate Resistant Limestone Cement is labeled as “HSL”. The name of the mix also notes whether it is “air entrained” and also includes other specifications of the mix recognized in the marketplace. For instance, mixes may also be tagged with an exposure class – (C) classes pertain to chloride exposure; (F) classes pertain to freezing and thawing exposure without chlorides; (N) class is exposed to neither chlorides nor freezing and thawing. For more information concerning exposure class see CSA standard A23.1.

SCM Replacement: Identify the supplementary cementing material (SCM) percentage. Fly ash is labeled in the mix designs as “FA”. For example, a mix with 20% fly ash is denoted in the mix identifier as “20 FA”.

Cut-off Rules

The cut-off criteria for all activity stage flows considered within the system boundary conform with ISO 14044:2006 and NSF PCR 2021. Specifically, the cut-off criteria were applied as follows:

- All inputs and outputs for which data are available are included in the calculated effects and no collected core process data are excluded.
- A one percent cut-off is considered for renewable and non-renewable primary energy consumption and the total mass of inputs within a unit process. The sum of the total neglected flows does not exceed 5% of all energy consumption and mass of inputs.
- All flows known to contribute a significant impact or to uncertainty are included.
- The cut-off rules are not applied to hazardous and toxic materials – all are included in the life cycle inventory.

Allocation

The allocation of co-products or secondary flows cross the system boundary conforms with ISO 21930: 2017 Section 7.2.4. Specifically, the allocation criteria were applied as follows:

- Allocation was not applied any of the gate-to-gate production facilities. For facilities that manufacture additional products (i.e. aggregate), the LCI flows at the facility specific to the concrete production were reported.
- For secondary data sources, the NSF PCR default allocation selection (i.e. “Cut-off” or “Alloc Rec”) was applied.
- The product category rules for this EPD recognize fly ash, slag, silica fume, metakaloin, and pumice as recovered materials and thus the environmental impacts allocated to these materials are limited to the treatment and transportation required to use as a concrete material input
- A portion (30%) of the reported fleet energy use for truck mixing plants was allocated to the mixing facility.

Participation

Participation in the concrete plant data collection was open to all members of the Ready Mixed Concrete Association of Alberta (Concrete Alberta). Concrete plants were randomly selected based on size of operation and geographic distribution. The results of this report are applicable to the concrete produced from all members of Concrete Alberta and a list of certified concrete plants can be found on the Association website (www.concretealberta.ca).

Data Sources and Software

This EPD is based on foreground LCI data collected from the participating companies' production facilities. A representative sample of Concrete Alberta member facilities were selected based on technical attributes, production scale, and geographic location. In total, 25 facilities operated by Concrete Alberta member companies completed LCI data collection questionnaires representing over 20% of all Concrete Alberta member facilities.

All upstream material, resource and energy carrier inputs have been sourced from various industry-average datasets and literature as specified for use in NSF PCR 2021. Tables 1 to 3 describe each LCI data source for raw materials (A1), transportation by mode (A2), the core manufacture process (A3), and descriptions of data quality for each data source.

This EPD was calculated using manufacturer specific cement data that represents 100% of the total cement used in this mix. As part of the data collection process, each participating facility provided data as to their cement supplier. All cement facilities were represented with environmental product declarations, and thus a weighted average cement profile was created for each individual region.

Table 1. A1 - Raw Material Supply				
Materials	LCI Data Source	Geography	Year	Data Quality Assessment
General Use Cement ASTM C150, C595, C1157, CSA A3000	Weighted Average of Results Specific to Concrete Producers in Region	Canada	2020-2021	<ul style="list-style-type: none"> • Technology: very good • Time: very good • Geography: very good • Completeness: very good • Reliability: very good
General Use Limestone Cement ASTM C150, C595, C1157, CSA A3000	Weighted Average of Results Specific to Concrete Producers in Region	Canada	2020-2021	<ul style="list-style-type: none"> • Technology: very good • Time: very good • Geography: very good • Completeness: very good • Reliability: very good
Fly Ash ASTM C618, CSA A3000	None, no incoming burden, only inbound transport was considered	N/A	N/A	<ul style="list-style-type: none"> • N/A • Recovered material
Slag Cement ASTM C989, CSA A3000	Slag Cement Association N. America EPD Slag Cement, 2021	N. America	2021	<ul style="list-style-type: none"> • Technology: good • Time: good • Geography: good • Completeness: good • Reliability: very good, third-party verified EPD
Crushed Aggregates coarse and fine ASTM C33, CSA A23.1/A23.2	ecoinvent 3.4: Gravel, crushed {RoW} production Cut-off, U Modified with regional electricity	EU/Canada	2004	<ul style="list-style-type: none"> • Technology: good • Time: fair
Natural Aggregates coarse and fine ASTM C30, CSA A23.1/A23.2	ecoinvent 3.4: Gravel, round {RoW} gravel and sand quarry operation Cut-off, U Modified with regional electricity	EU/Canada	2004	<ul style="list-style-type: none"> • Technology: good • Time: fair • Geography: good • Completeness: very good • Reliability: very good
Admixtures ASTM C494, ASTM C260	EFCA EPDs for Air Entrainers, Plasticisers and superplasticisers (2015) Non-supported LCIA indicators estimated	EU	2015	<ul style="list-style-type: none"> • Technology: very good • Time: good • Geography: good • Completeness: good • Reliability: good
Water ASTM C1602, CSA A23.1/A23.2	ecoinvent 3.4: Tap water {RoW} market for Cut-off, U	Global	2011	<ul style="list-style-type: none"> • Technology: good • Time: good • Geography: good • Completeness: good • Reliability: very good, third-party verified EPD

Table 2. A2 - Transportation				
Process	LCI Data Source	Geography	Year	Data Quality Assessment
Truck Transportation	USLCI 2014: Transport, combination truck, short-haul, diesel powered/tkm/RNA	USA	2007	<ul style="list-style-type: none"> • Technology: good • Time: fair • Geography: very good • Completeness: good • Reliability: good
Rail Transportation	USLCI 2014: Transport, train, diesel powered /US U	USA	2007	<ul style="list-style-type: none"> • Technology: good • Time: fair • Geography: very good • Completeness: good • Reliability: good
Ocean Transportation	USLCI 2014: Transport, ocean freighter, average fuel mix /US U	USA	2007	<ul style="list-style-type: none"> • Technology: good • Time: fair • Geography: very good • Completeness: good • Reliability: good

Table 3. A3 - Manufacturing				
Process	LCI Data Source	Geography	Year	Data Quality Assessment
Electricity	ecoinvent 3.4: Electricity, low voltage, at grid, (CA)	Regional	2015	<ul style="list-style-type: none"> • Technology: very good • Time: good • Geography: very good • Completeness: good • Reliability: good
Natural Gas	USLCI 2014: Natural gas, combusted in industrial boiler/US	US	2008	<ul style="list-style-type: none"> • Technology: very good • Time: fair • Geography: fair • Completeness: good • Reliability: good
Diesel	USLCI 2014: Diesel, combusted in industrial equipment/US	US	2008	<ul style="list-style-type: none"> • Technology: very good • Time: fair • Geography: fair • Completeness: good • Reliability: good
Liquefied Propane Gas	USLCI 2014: Liquefied petroleum gas, combusted in industrial boiler/US	US	2008	<ul style="list-style-type: none"> • Technology: very good • Time: fair • Geography: fair • Completeness: good • Reliability: good
Hazardous Waste	ecoinvent 3.4: Hazardous waste, for incineration {ROW} treatment of hazardous waste, hazardous waste incineration Alloc Rec, U	EU	2008	<ul style="list-style-type: none"> • Technology: good • Time: fair • Geography: fair • Completeness: very good • Reliability: very good
Non-Hazardous Waste	ecoinvent 3.4: Inert waste {RoW} treatment of, sanitary landfill Alloc Rec, U	EU	2008	<ul style="list-style-type: none"> • Technology: good • Time: fair • Geography: fair • Completeness: very good • Reliability: very good

Athena's Concrete LCA Software V2 was used to gather the facility data, mix designs, and to conduct the LCA modeling. This software was third party reviewed and found to be in conformance with the following relevant standards: ISO 14040:2006b, ISO 14044:2006c, ISO 14025:2006, ISO 21930:2017, and the NSF PCR 2021.

Life Cycle Assessment Results

The LCA results presented in this EPD are intended for use in Business to Business (B-to-B) communication. The EPD supports 25 life cycle impact assessment indicators and inventory metrics as listed in Table 4. The Impact Assessment method and other calculation methodologies are specified in Table 4. Tables 5 through 25 present the LCA results for the mixes produced at the different facilities (Information module A1-A3 accumulated). The results are presented first based on a declared unit of 1 cubic metre.

Table 4. Life Cycle Category Indicators and Inventory Metrics			
Core Mandatory Impact Indicator	Abbreviation	Unit	Method/Source
Global warming potential	GWP	kg CO ₂ eq	TRACI 2.1 V1.02
Depletion potential of the stratospheric ozone layer	ODP	kg CFC-11 eq	TRACI 2.1 V1.02
Acidification potential of soil and water sources	AP	kg SO ₂ eq	TRACI 2.1 V1.02
Eutrophication potential	EP	kg N eq	TRACI 2.1 V1.02
Photochemical smog creation potential	POCP	kg O ₃ eq	TRACI 2.1 V1.02
Abiotic depletion potential (ADP _{fossil})*	ADPf	MJ, NCV	CML-IA Baseline V3.02
Abiotic depletion potential (ADP _{elements})*	ADPe	kg Sbe	CML-IA Baseline V3.02
Use of Primary Resources			
Renewable primary energy carrier used as energy*	RPRE	MJ, NCV	CED V1.10 NCV
Renewable primary energy carrier used as material*	RPRM	MJ, NCV	LCI Indicator
Non-renewable primary energy carrier used as energy*	NRPRE	MJ, NCV	CED V1.10 NCV
Non-renewable primary energy carrier used as material*	NRPRM	MJ, NCV	LCI Indicator
Secondary Material, Secondary Fuel and Recovered Energy			
Secondary material*	SM	kg	LCI Indicator
Renewable secondary fuel *	RSF	MJ, NCV	LCI Indicator
Non-renewable secondary fuel*	NRSF	MJ, NCV	LCI Indicator
Recovered energy*	RE	MJ, NCV	LCI Indicator
Mandatory Inventory Parameters			
Consumption of freshwater resources;	FW	m ³	LCI Indicator
Calcination and carbonation emissions	CCE	kg CO ₂ e	LCI Indicator
Indicators Describing Waste			
Hazardous waste disposed*	HWD	kg	LCI Indicator
Non-hazardous waste disposed*	NHWD	kg	LCI Indicator
High-level radioactive waste*	HLRW	m ³	LCI Indicator
Intermediate- and low-level radioactive waste*	ILLRW	m ³	LCI Indicator
Components for re-use*	CRU	kg	LCI Indicator
Materials for recycling*	MR	kg	LCI Indicator
Materials for energy recovery*	MER	kg	LCI Indicator
Recovered energy exported from the product system*	EE	MJ, NCV	LCI Indicator

Emerging LCA impact categories and inventory items are still under development and can have high levels of uncertainty that preclude international acceptance pending further development. Use caution when interpreting data in categories marked with (*) in Table 4. Additionally, EPDs are comparable only if they comply with this document, use the same sub-category PCR where applicable, include all relevant information modules and are based on equivalent scenarios with respect to the context of construction works. No regulated substances of very high concern were identified in the LCA.

Table 5. LCA Results 20 MPa concrete with air GU

Unit		Baseline 20 MPa concrete with air GU/HS 10 FA	20 MPa concrete with air GU/HS	20 MPa concrete with air GU/HS 10 FA	20 MPa concrete with air GU/HS 20 FA	20 MPa concrete with air GUL/HSL	20 MPa concrete with air GUL/HSL 10 FA	20 MPa concrete with air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO ₂ eq.	273.04	298.14	273.04	247.94	269.42	247.18	224.93
ODP	kg CFC-11 eq.	7.87E-06	8.66E-06	7.87E-06	7.08E-06	8.31E-06	7.56E-06	6.80E-06
EP	kg N eq.	0.51	0.54	0.51	0.47	0.52	0.49	0.46
AP	kg SO ₂ eq.	1.15	1.23	1.15	1.07	1.14	1.07	1.00
POCP	kg O ₃ eq.	21.81	23.20	21.81	20.42	21.35	20.14	18.93
Use of primary resources								
RPR _E	MJ, NCV	39.13	42.08	39.13	36.18	49.07	45.43	41.78
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1951.21	2093.76	1951.21	1808.67	1700.18	1596.73	1493.27
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	41.32	45.88	41.32	36.77	41.48	37.36	33.24
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADPf	MJ, LHV	1081.12	1133.20	1081.12	1029.05	1043.53	1000.36	957.19
ADPe	kg Sb	1.14E-04	1.18E-04	1.14E-04	1.11E-04	1.17E-04	1.14E-04	1.10E-04
Consumption of freshwater resources								
FW	m ³	1.58	1.61	1.58	1.55	1.58	1.55	1.53
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	20.32	22.56	20.32	18.09	20.37	18.35	16.33
HLRW	m ³	1.18E-09	1.18E-09	1.18E-09	1.18E-09	1.18E-09	1.18E-09	1.18E-09
ILLRW	m ³	5.75E-08	5.75E-08	5.75E-08	5.75E-08	5.75E-08	5.75E-08	5.75E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO ₂ eq.	127.48	141.54	127.48	113.43	123.37	111.12	98.87

Table 6. LCA Results 20 MPa concrete without air GU

Unit		Baseline 20 MPa concrete without air GU/HS 10 FA	20 MPa concrete without air GU/HS	20 MPa concrete without air GU/HS 10 FA	20 MPa concrete without air GU/HS 20 FA	20 MPa concrete without air GUL/HSL	20 MPa concrete without air GUL/HSL 10 FA	20 MPa concrete without air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO2 eq.	260.95	285.19	260.95	237.59	257.95	236.47	215.76
ODP	kg CFC-11 eq.	7.50E-06	8.27E-06	7.50E-06	6.77E-06	7.94E-06	7.21E-06	6.50E-06
EP	kg N eq.	0.49	0.53	0.49	0.46	0.51	0.48	0.44
AP	kg SO2 eq.	1.11	1.19	1.11	1.03	1.10	1.03	0.97
POCP	kg O3 eq.	21.12	22.47	21.12	19.83	20.72	19.55	18.42
Use of primary resources								
RPR _E	MJ, NCV	37.96	40.80	37.96	35.21	47.44	43.92	40.53
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1881.58	2019.21	1881.58	1748.87	1645.86	1545.97	1449.64
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	39.12	43.52	39.12	34.88	39.35	35.37	31.54
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1055.14	1105.41	1055.14	1006.65	1020.35	978.67	938.48
ADP _e	kg Sb	1.18E-04	1.21E-04	1.18E-04	1.15E-04	1.21E-04	1.17E-04	1.14E-04
Consumption of freshwater resources								
FW	m ³	1.62	1.64	1.62	1.59	1.61	1.59	1.57
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	19.24	21.40	19.24	17.16	19.33	17.38	15.50
HLRW	m ³	1.21E-09	1.21E-09	1.21E-09	1.21E-09	1.21E-09	1.21E-09	1.21E-09
ILLRW	m ³	5.94E-08	5.94E-08	5.94E-08	5.94E-08	5.94E-08	5.94E-08	5.94E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	120.70	134.27	120.70	107.61	117.03	105.20	93.80

Table 7. LCA Results 25 MPa concrete with air GU

Unit	Baseline 25 MPa concrete with air GU/HS 10 FA	25 MPa concrete with air GU/HS	25 MPa concrete with air GU/HS 10 FA	25 MPa concrete with air GU/HS 20 FA	25 MPa concrete with air GUL/HSL	25 MPa concrete with air GUL/HSL 10 FA	25 MPa concrete with air GUL/HSL 20 FA
Environmental impacts							
GWP	kg CO2 eq.	318.42	348.71	318.42	288.13	314.49	260.79
ODP	kg CFC-11 eq.	9.23E-06	1.02E-05	9.23E-06	8.27E-06	9.76E-06	7.94E-06
EP	kg N eq.	0.57	0.61	0.57	0.53	0.59	0.51
AP	kg SO2 eq.	1.31	1.41	1.31	1.21	1.30	1.13
POCP	kg O3 eq.	24.71	26.40	24.71	23.03	24.19	21.27
Use of primary resources							
RPR _E	MJ, NCV	45.50	49.06	45.50	41.94	57.40	48.60
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2233.17	2405.21	2233.17	2061.14	1936.16	1686.44
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources							
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	49.18	54.68	49.18	43.68	49.43	39.49
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential							
ADP _f	MJ, LHV	1205.04	1267.88	1205.04	1142.19	1161.02	1056.82
ADP _e	kg Sb	1.33E-04	1.37E-04	1.33E-04	1.29E-04	1.36E-04	1.28E-04
Consumption of freshwater resources							
FW	m ³	1.62	1.65	1.62	1.59	1.62	1.56
Waste and output flows							
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	24.18	26.88	24.18	21.48	24.27	19.40
HLRW	m ³	1.18E-09	1.18E-09	1.18E-09	1.18E-09	1.18E-09	1.18E-09
ILLRW	m ³	5.68E-08	5.68E-08	5.68E-08	5.68E-08	5.68E-08	5.68E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency							
CCE	kg CO2 eq.	151.72	168.68	151.72	134.75	147.03	117.46

Table 8. LCA Results 25 MPa concrete without air & 0.55 W/CM ratio (N-CF) GU

Unit	Baseline 25 MPa concrete without air & 0.55 W/CM ratio (N-CF) GU/HS 10	25 MPa concrete without air & 0.55 W/CM ratio (N-CF) GU/HS	25 MPa concrete without air & 0.55 W/CM ratio (N-CF) GU/HS 10 FA	25 MPa concrete without air & 0.55 W/CM ratio (N-CF) GU/HS 20 FA	25 MPa concrete without air & 0.55 W/CM ratio (N-CF) GUL/HSL	25 MPa concrete without air & 0.55 W/CM ratio (N-CF) GUL/HSL 10 FA	25 MPa concrete without air & 0.55 W/CM ratio (N-CF) GUL/HSL 20 FA	
Environmental impacts								
GWP	kg CO2 eq.	306.32	334.88	306.32	276.86	302.23	276.92	250.80
ODP	kg CFC-11 eq.	8.86E-06	9.76E-06	8.86E-06	7.93E-06	9.36E-06	8.50E-06	7.62E-06
EP	kg N eq.	0.56	0.60	0.56	0.51	0.57	0.53	0.50
AP	kg SO2 eq.	1.27	1.36	1.27	1.17	1.26	1.18	1.09
POCP	kg O3 eq.	24.02	25.60	24.02	22.37	23.50	22.12	20.69
Use of primary resources								
RPR _E	MJ, NCV	44.33	47.68	44.33	40.87	55.64	51.49	47.21
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2162.93	2325.13	2162.93	1995.31	1877.65	1759.92	1638.13
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	46.98	52.16	46.98	41.64	47.16	42.47	37.64
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADPF	MJ, LHV	1178.45	1237.70	1178.45	1116.92	1135.75	1086.63	1035.54
ADPe	kg Sb	1.37E-04	1.41E-04	1.37E-04	1.33E-04	1.40E-04	1.36E-04	1.32E-04
Consumption of freshwater resources								
FW	m ³	1.65	1.68	1.65	1.61	1.64	1.62	1.59
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	23.10	25.65	23.10	20.48	23.16	20.86	18.49
HLRW	m ³	1.20E-09	1.20E-09	1.20E-09	1.20E-09	1.20E-09	1.20E-09	1.20E-09
ILLRW	m ³	5.87E-08	5.87E-08	5.87E-08	5.87E-08	5.87E-08	5.87E-08	5.87E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	144.93	160.93	144.93	128.45	140.27	126.33	111.96

Table 9. LCA Results 30 MPa concrete with air GU

Unit		Baseline 30 MPa concrete with air GU/HS 10 FA	30 MPa concrete with air GU/HS	30 MPa concrete with air GU/HS 10 FA	30 MPa concrete with air GU/HS 20 FA	30 MPa concrete with air GUL/HSL	30 MPa concrete with air GUL/HSL 10 FA	30 MPa concrete with air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO ₂ eq.	368.87	404.35	368.87	333.38	364.14	332.68	301.23
ODP	kg CFC-11 eq.	1.07E-05	1.18E-05	1.07E-05	9.59E-06	1.13E-05	1.03E-05	9.21E-06
EP	kg N eq.	0.64	0.69	0.64	0.59	0.66	0.61	0.57
AP	kg SO ₂ eq.	1.48	1.60	1.48	1.37	1.47	1.37	1.27
POCP	kg O ₃ eq.	27.83	29.80	27.83	25.85	27.21	25.49	23.78
Use of primary resources								
RPR _E	MJ, NCV	54.69	58.86	54.69	50.52	68.66	63.50	58.35
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2557.62	2759.15	2557.62	2356.09	2207.88	2061.62	1915.35
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	57.82	64.26	57.82	51.38	58.10	52.28	46.45
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1354.72	1428.34	1354.72	1281.10	1302.74	1241.71	1180.68
ADP _e	kg Sb	1.75E-04	1.80E-04	1.75E-04	1.70E-04	1.79E-04	1.74E-04	1.69E-04
Consumption of freshwater resources								
FW	m ³	1.64	1.68	1.64	1.60	1.64	1.61	1.57
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	28.42	31.59	28.42	25.26	28.52	25.67	22.81
HLRW	m ³	1.16E-09	1.16E-09	1.16E-09	1.16E-09	1.16E-09	1.16E-09	1.16E-09
ILLRW	m ³	5.50E-08	5.50E-08	5.50E-08	5.50E-08	5.50E-08	5.50E-08	5.50E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO ₂ eq.	178.38	198.25	178.38	158.51	172.81	155.48	138.16

Table 10. LCA Results 30 MPa concrete with air (S-3 exposed to F/T) GU

Unit	Baseline 30 MPa concrete with air (S-3 exposed to F/T) GU/HS 20 FA	30 MPa concrete with air (S-3 exposed to F/T) GU/HS	30 MPa concrete with air (S-3 exposed to F/T) GU/HS 10 FA	30 MPa concrete with air (S-3 exposed to F/T) GU/HS 20 FA	30 MPa concrete with air (S-3 exposed to F/T) GUL/HSL	30 MPa concrete with air (S-3 exposed to F/T) GUL/HSL 10 FA	30 MPa concrete with air (S-3 exposed to F/T) GUL/HSL 20 FA	
Environmental impacts								
GWP	kg CO2 eq.	309.16	374.07	342.08	309.16	337.20	308.85	279.66
ODP	kg CFC-11 eq.	8.87E-06	1.09E-05	9.90E-06	8.87E-06	1.05E-05	9.50E-06	8.51E-06
EP	kg N eq.	0.56	0.65	0.60	0.56	0.62	0.58	0.54
AP	kg SO2 eq.	1.28	1.49	1.39	1.28	1.38	1.29	1.19
POCP	kg O3 eq.	24.32	27.92	26.15	24.32	25.55	24.01	22.42
Use of primary resources								
RPR _E	MJ, NCV	47.47	55.11	51.34	47.47	64.09	59.44	54.66
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2208.98	2577.63	2396.26	2208.98	2072.19	1940.69	1804.62
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	47.14	58.92	53.11	47.14	53.27	48.01	42.62
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1218.98	1353.65	1287.68	1218.98	1238.49	1183.89	1126.85
ADP _e	kg Sb	1.64E-04	1.73E-04	1.69E-04	1.64E-04	1.72E-04	1.68E-04	1.63E-04
Consumption of freshwater resources								
FW	m ³	1.60	1.67	1.63	1.60	1.63	1.60	1.57
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	23.18	28.96	26.11	23.18	26.16	23.58	20.93
HLRW	m ³	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09
ILLRW	m ³	5.62E-08	5.62E-08	5.62E-08	5.62E-08	5.62E-08	5.62E-08	5.62E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	145.42	181.77	163.84	145.42	158.44	142.81	126.75

Table 11. LCA Results 30 MPa concrete without air GU

Unit		Baseline 30 MPa concrete without air GU/HS 10 FA	30 MPa concrete without air GU/HS	30 MPa concrete without air GU/HS 10 FA	30 MPa concrete without air GU/HS 20 FA	30 MPa concrete without air GUL/HSL	30 MPa concrete without air GUL/HSL 10 FA	30 MPa concrete without air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO2 eq.	334.47	365.60	334.47	302.42	329.71	302.12	273.70
ODP	kg CFC-11 eq.	9.67E-06	1.07E-05	9.67E-06	8.67E-06	1.02E-05	9.28E-06	8.32E-06
EP	kg N eq.	0.59	0.64	0.59	0.55	0.61	0.57	0.53
AP	kg SO2 eq.	1.37	1.47	1.37	1.26	1.36	1.27	1.18
POCP	kg O3 eq.	25.76	27.48	25.76	23.97	25.17	23.68	22.12
Use of primary resources								
RPR _E	MJ, NCV	50.52	54.18	50.52	46.75	62.92	58.40	53.75
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2352.31	2528.76	2352.31	2169.94	2036.80	1908.87	1776.37
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	51.69	57.35	51.69	45.88	51.85	46.74	41.48
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1271.70	1335.87	1271.70	1204.79	1223.78	1170.67	1115.12
ADP _e	kg Sb	1.72E-04	1.76E-04	1.72E-04	1.67E-04	1.75E-04	1.71E-04	1.67E-04
Consumption of freshwater resources								
FW	m ³	1.66	1.70	1.66	1.63	1.66	1.63	1.60
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	25.42	28.19	25.42	22.56	25.46	22.95	20.37
HLRW	m ³	1.20E-09	1.20E-09	1.20E-09	1.20E-09	1.20E-09	1.20E-09	1.20E-09
ILLRW	m ³	5.83E-08	5.83E-08	5.83E-08	5.83E-08	5.83E-08	5.83E-08	5.83E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	159.47	176.92	159.47	141.54	154.21	139.00	123.37

Table 12. LCA Results 30 MPa concrete without air (S-3 with no F/T) GU

Unit	Baseline 30 MPa concrete without air (S-3 with no F/T) GU/HS 20 FA	30 MPa concrete without air (S-3 with no F/T) GU/HS	30 MPa concrete without air (S-3 with no F/T) GU/HS 10 FA	30 MPa concrete without air (S-3 with no F/T) GU/HS 20 FA	30 MPa concrete without air (S-3 with no F/T) GUL/HSL	30 MPa concrete without air (S-3 with no F/T) GUL/HSL 10 FA	30 MPa concrete without air (S-3 with no F/T) GUL/HSL 20 FA	
Environmental impacts								
GWP	kg CO2 eq.	296.50	357.08	326.79	296.50	322.67	295.82	268.97
ODP	kg CFC-11 eq.	8.32E-06	1.02E-05	9.28E-06	8.32E-06	9.81E-06	8.90E-06	7.99E-06
EP	kg N eq.	0.54	0.62	0.58	0.54	0.60	0.56	0.52
AP	kg SO2 eq.	1.24	1.43	1.33	1.24	1.33	1.24	1.15
POCP	kg O3 eq.	23.17	26.53	24.85	23.17	24.32	22.86	21.40
Use of primary resources								
RPR _E	MJ, NCV	60.31	67.43	63.87	60.31	75.82	71.42	67.02
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2221.98	2566.06	2394.02	2221.98	2094.31	1969.45	1844.59
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	43.99	54.99	49.49	43.99	49.72	44.75	39.77
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1287.43	1413.12	1350.27	1287.43	1305.64	1253.54	1201.44
ADP _e	kg Sb	3.12E-04	3.21E-04	3.17E-04	3.12E-04	3.20E-04	3.16E-04	3.12E-04
Consumption of freshwater resources								
FW	m ³	1.63	1.70	1.66	1.63	1.66	1.63	1.60
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	21.64	27.04	24.34	21.64	24.41	21.98	19.54
HLRW	m ³	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09
ILLRW	m ³	5.62E-08	5.62E-08	5.62E-08	5.62E-08	5.62E-08	5.62E-08	5.62E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	135.72	169.65	152.69	135.72	147.88	133.09	118.30

Table 13. LCA Results 32 MPa concrete with air & 0.45 W/CM ratio (C-2) GU

Unit	Baseline 32 MPa concrete with air & 0.45 W/CM ratio (C-2) GU/HS 10 FA	32 MPa concrete with air & 0.45 W/CM ratio (C-2) GU/HS	32 MPa concrete with air & 0.45 W/CM ratio (C-2) GU/HS 10 FA	32 MPa concrete with air & 0.45 W/CM ratio (C-2) GU/HS 20 FA	32 MPa concrete with air & 0.45 W/CM ratio (C-2) GU/HSL	32 MPa concrete with air & 0.45 W/CM ratio (C-2) GUL/HSL 10 FA	32 MPa concrete with air & 0.45 W/CM ratio (C-2) GUL/HSL 20 FA
Environmental impacts							
GWP	kg CO2 eq.	396.85	434.93	396.85	358.80	391.37	323.89
ODP	kg CFC-11 eq.	1.15E-05	1.27E-05	1.15E-05	1.03E-05	1.22E-05	9.93E-06
EP	kg N eq.	0.68	0.73	0.68	0.62	0.70	0.60
AP	kg SO2 eq.	1.58	1.70	1.58	1.46	1.57	1.35
POCP	kg O3 eq.	29.57	31.68	29.57	27.46	28.88	25.21
Use of primary resources							
RPR _E	MJ, NCV	58.68	63.16	58.68	54.20	73.77	62.71
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2730.57	2946.84	2730.57	2514.80	2349.75	2036.31
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources							
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	62.69	69.60	62.69	55.78	62.93	50.43
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential							
ADP _f	MJ, LHV	1429.77	1508.78	1429.77	1351.24	1372.74	1242.22
ADP _e	kg Sb	1.86E-04	1.91E-04	1.86E-04	1.81E-04	1.90E-04	1.80E-04
Consumption of freshwater resources							
FW	m ³	1.66	1.70	1.66	1.62	1.65	1.58
Waste and output flows							
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	30.82	34.21	30.82	27.42	30.89	24.76
HLRW	m ³	1.16E-09	1.16E-09	1.16E-09	1.16E-09	1.16E-09	1.16E-09
ILLRW	m ³	5.39E-08	5.39E-08	5.39E-08	5.39E-08	5.39E-08	5.39E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency							
CCE	kg CO2 eq.	193.41	214.73	193.41	172.08	187.17	149.99

Table 14. LCA Results 32 MPa concrete with air (S-2 exposed to F/T) GU

Unit	Baseline 32 MPa concrete with air (S-2 exposed to F/T) GU/HS 20 FA	32 MPa concrete with air (S-2 exposed to F/T) GU/HS	32 MPa concrete with air (S-2 exposed to F/T) GU/HS 10 FA	32 MPa concrete with air (S-2 exposed to F/T) GU/HS 20 FA	32 MPa concrete with air (S-2 exposed to F/T) GU/HS 10 FA	32 MPa concrete with air (S-2 exposed to F/T) GU/HS 20 FA	32 MPa concrete with air (S-2 exposed to F/T) GU/HS 10 FA	32 MPa concrete with air (S-2 exposed to F/T) GU/HS 20 FA
Environmental impacts								
GWP	kg CO ₂ eq.	326.84	396.08	361.46	326.84	356.75	326.06	295.38
ODP	kg CFC-11 eq.	9.41E-06	1.16E-05	1.05E-05	9.41E-06	1.11E-05	1.01E-05	9.03E-06
EP	kg N eq.	0.58	0.68	0.63	0.58	0.65	0.60	0.56
AP	kg SO ₂ eq.	1.35	1.57	1.46	1.35	1.45	1.35	1.25
POCP	kg O ₃ eq.	25.46	29.30	27.38	25.46	26.77	25.10	23.43
Use of primary resources								
RPR _E	MJ, NCV	49.09	57.23	53.16	49.09	66.81	61.78	56.76
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2311.28	2704.51	2507.90	2311.28	2165.37	2022.67	1879.97
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	50.28	62.85	56.56	50.28	56.82	51.14	45.46
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1258.73	1402.38	1330.55	1258.73	1279.54	1220.00	1160.46
ADP _e	kg Sb	1.64E-04	1.73E-04	1.69E-04	1.64E-04	1.72E-04	1.68E-04	1.63E-04
Consumption of freshwater resources								
FW	m ³	1.61	1.68	1.64	1.61	1.64	1.61	1.57
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	24.72	30.89	27.81	24.72	27.90	25.11	22.32
HLRW	m ³	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09
ILLRW	m ³	5.54E-08	5.54E-08	5.54E-08	5.54E-08	5.54E-08	5.54E-08	5.54E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO ₂ eq.	155.11	193.89	174.50	155.11	169.00	152.10	135.20

Table 15. LCA Results 32 MPa concrete without air (S-2 with no F/T) GU

	Unit	Baseline 32 MPa concrete without air (S-2 with no F/T) GU/HS 20 FA	32 MPa concrete without air (S-2 with no F/T) GU/HS	32 MPa concrete without air (S-2 with no F/T) GU/HS 10 FA	32 MPa concrete without air (S-2 with no F/T) GU/HS 20 FA	32 MPa concrete without air (S-2 with no F/T) GU/HS	32 MPa concrete without air (S-2 with no F/T) GU/HS 10 FA	32 MPa concrete without air (S-2 with no F/T) GU/HS 20 FA
Environmental impacts								
GWP	kg CO ₂ eq.	313.61	380.25	347.39	313.61	342.39	313.27	283.32
ODP	kg CFC-11 eq.	9.03E-06	1.11E-05	1.01E-05	9.03E-06	1.07E-05	9.68E-06	8.67E-06
EP	kg N eq.	0.55	0.64	0.60	0.55	0.61	0.57	0.53
AP	kg SO ₂ eq.	1.30	1.51	1.41	1.30	1.40	1.30	1.21
POCP	kg O ₃ eq.	24.75	28.45	26.63	24.75	26.01	24.43	22.80
Use of primary resources								
RPR _E	MJ, NCV	43.73	51.56	47.70	43.73	60.79	56.01	51.11
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2204.63	2583.11	2396.83	2204.63	2064.19	1929.13	1789.49
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	48.39	60.49	54.52	48.39	54.69	49.29	43.75
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1193.25	1331.52	1263.76	1193.25	1213.29	1157.20	1098.67
ADP _e	kg Sb	1.18E-04	1.27E-04	1.23E-04	1.18E-04	1.26E-04	1.22E-04	1.17E-04
Consumption of freshwater resources								
FW	m ³	1.66	1.73	1.70	1.66	1.69	1.66	1.63
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	23.80	29.74	26.80	23.80	26.85	24.20	21.49
HLRW	m ³	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09	1.04E-09
ILLRW	m ³	5.29E-08	5.29E-08	5.29E-08	5.29E-08	5.29E-08	5.29E-08	5.29E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO ₂ eq.	149.30	186.62	168.20	149.30	162.67	146.61	130.13

Table 16. LCA Results 35 MPa concrete with air & 0.40 W/CM ratio (C-1/A-1/S-1) GU

Unit	Baseline 35 MPa concrete with air & 0.40 W/CM ratio (C-1/A-1/S-1) GU/HS 20	35 MPa concrete with air & 0.40 W/CM ratio (C-1/A-1/S-1) GU/HS	35 MPa concrete with air & 0.40 W/CM ratio (C-1/A-1/S-1) GU/HS 10 FA	35 MPa concrete with air & 0.40 W/CM ratio (C-1/A-1/S-1) GU/HS 20 FA	35 MPa concrete with air & 0.40 W/CM ratio (C-1/A-1/S-1) GUL/HSL	35 MPa concrete with air & 0.40 W/CM ratio (C-1/A-1/S-1) GUL/HSL 10 FA	35 MPa concrete with air & 0.40 W/CM ratio (C-1/A-1/S-1) GUL/HSL 20 FA	
Environmental impacts								
GWP	kg CO2 eq.	363.13	441.02	402.08	363.13	396.77	362.25	327.73
ODP	kg CFC-11 eq.	1.05E-05	1.29E-05	1.17E-05	1.05E-05	1.24E-05	1.12E-05	1.00E-05
EP	kg N eq.	0.63	0.74	0.68	0.63	0.71	0.65	0.60
AP	kg SO ₂ eq.	1.47	1.72	1.60	1.47	1.59	1.47	1.36
POCP	kg O ₃ eq.	27.71	32.04	29.87	27.71	29.18	27.31	25.43
Use of primary resources								
RPR _E	MJ, NCV	55.07	64.22	59.65	55.07	75.00	69.35	63.69
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2540.24	2982.62	2761.43	2540.24	2376.09	2215.56	2055.02
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	56.56	70.70	63.63	56.56	63.92	57.53	51.14
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1361.13	1522.74	1441.94	1361.13	1384.55	1317.57	1250.58
ADP _e	kg Sb	1.87E-04	1.98E-04	1.92E-04	1.87E-04	1.97E-04	1.91E-04	1.86E-04
Consumption of freshwater resources								
FW	m ³	1.61	1.69	1.65	1.61	1.64	1.61	1.57
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	27.81	34.75	31.28	27.81	31.38	28.24	25.11
HLRW	m ³	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09
ILLRW	m ³	5.30E-08	5.30E-08	5.30E-08	5.30E-08	5.30E-08	5.30E-08	5.30E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	174.50	218.13	196.31	174.50	190.13	171.12	152.10

Table 17. LCA Results 35 MPa concrete with air GU

Unit		Baseline 35 MPa concrete with air GU/HS 15 FA	35 MPa concrete with air GU/HS	35 MPa concrete with air GU/HS 10 FA	35 MPa concrete with air GU/HS 20 FA	35 MPa concrete with air GUL/HSL	35 MPa concrete with air GUL/HSL 10 FA	35 MPa concrete with air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO2 eq.	409.82	473.00	431.49	389.05	425.31	388.52	350.89
ODP	kg CFC-11 eq.	1.19E-05	1.39E-05	1.26E-05	1.12E-05	1.33E-05	1.21E-05	1.08E-05
EP	kg N eq.	0.69	0.78	0.72	0.66	0.75	0.69	0.64
AP	kg SO2 eq.	1.63	1.84	1.70	1.57	1.69	1.57	1.45
POCP	kg O3 eq.	30.55	34.06	31.77	29.40	30.99	29.00	26.94
Use of primary resources								
RPR _E	MJ, NCV	61.58	69.01	64.12	59.14	80.62	74.59	68.43
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2825.86	3184.68	2949.24	2707.89	2530.97	2360.23	2184.93
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	64.73	76.20	68.66	60.96	68.90	62.08	55.12
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1482.74	1613.82	1528.10	1439.64	1464.88	1393.90	1320.49
ADP _e	kg Sb	2.03E-04	2.12E-04	2.06E-04	2.00E-04	2.11E-04	2.05E-04	1.99E-04
Consumption of freshwater resources								
FW	m ³	1.66	1.73	1.68	1.64	1.68	1.64	1.60
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	31.82	37.45	33.75	29.97	33.82	30.47	27.06
HLRW	m ³	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09
ILLRW	m ³	5.30E-08	5.30E-08	5.30E-08	5.30E-08	5.30E-08	5.30E-08	5.30E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	199.71	235.09	211.83	188.07	204.92	184.64	163.93

Table 18. LCA Results 35 MPa concrete without air (S-1 with no F/T) GU

Unit	Baseline 35 MPa concrete without air (S-1 with no F/T) GU/HS 20 FA	35 MPa concrete without air (S-1 with no F/T) GU/HS	35 MPa concrete without air (S-1 with no F/T) GU/HS 10 FA	35 MPa concrete without air (S-1 with no F/T) GU/HS 20 FA	35 MPa concrete without air (S-1 with no F/T) GUL/HSL	35 MPa concrete without air (S-1 with no F/T) GUL/HSL 10 FA	35 MPa concrete without air (S-1 with no F/T) GUL/HSL 20 FA	
Environmental impacts								
GWP	kg CO2 eq.	328.02	397.25	362.63	328.02	357.92	327.24	296.55
ODP	kg CFC-11 eq.	9.41E-06	1.16E-05	1.05E-05	9.41E-06	1.11E-05	1.01E-05	9.03E-06
EP	kg N eq.	0.58	0.68	0.63	0.58	0.65	0.60	0.56
AP	kg SO2 eq.	1.35	1.57	1.46	1.35	1.45	1.35	1.25
POCP	kg O3 eq.	25.51	29.35	27.43	25.51	26.82	25.15	23.48
Use of primary resources								
RPR _E	MJ, NCV	51.94	60.08	56.01	51.94	69.66	64.64	59.61
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2336.19	2729.42	2532.81	2336.19	2190.28	2047.58	1904.88
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	50.28	62.85	56.56	50.28	56.82	51.14	45.46
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1282.09	1425.74	1353.92	1282.09	1302.91	1243.36	1183.82
ADP _e	kg Sb	1.94E-04	2.03E-04	1.98E-04	1.94E-04	2.02E-04	1.98E-04	1.93E-04
Consumption of freshwater resources								
FW	m ³	1.61	1.69	1.65	1.61	1.65	1.62	1.58
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	24.72	30.89	27.81	24.72	27.90	25.11	22.32
HLRW	m ³	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09	1.17E-09
ILLRW	m ³	5.59E-08	5.59E-08	5.59E-08	5.59E-08	5.59E-08	5.59E-08	5.59E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	155.11	193.89	174.50	155.11	169.00	152.10	135.20

Table 19. LCA Results 40 MPa concrete with air GU

Unit		Baseline 40 MPa concrete with air GU/HS 15 FA	40 MPa concrete with air GU/HS	40 MPa concrete with air GU/HS 10 FA	40 MPa concrete with air GU/HS 20 FA	40 MPa concrete with air GUL/HSL	40 MPa concrete with air GUL/HSL 10 FA	40 MPa concrete with air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO2 eq.	426.88	492.66	448.49	405.24	443.00	403.84	365.52
ODP	kg CFC-11 eq.	1.23E-05	1.44E-05	1.30E-05	1.17E-05	1.38E-05	1.25E-05	1.12E-05
EP	kg N eq.	0.71	0.81	0.74	0.68	0.77	0.71	0.65
AP	kg SO2 eq.	1.69	1.90	1.76	1.62	1.75	1.62	1.50
POCP	kg O3 eq.	31.52	35.17	32.71	30.31	31.97	29.83	27.76
Use of primary resources								
RPR _E	MJ, NCV	68.44	76.17	70.98	65.90	88.27	81.86	75.57
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2960.44	3334.00	3082.82	2837.56	2653.34	2470.90	2293.03
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	67.40	79.35	71.33	63.48	71.74	64.49	57.39
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1561.19	1697.66	1605.60	1516.29	1542.57	1466.18	1392.23
ADP _e	kg Sb	2.55E-04	2.64E-04	2.58E-04	2.52E-04	2.63E-04	2.57E-04	2.51E-04
Consumption of freshwater resources								
FW	m ³	1.66	1.73	1.69	1.64	1.69	1.64	1.60
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	33.13	38.99	35.06	31.20	35.21	31.66	28.18
HLRW	m ³	1.13E-09	1.13E-09	1.13E-09	1.13E-09	1.13E-09	1.13E-09	1.13E-09
ILLRW	m ³	5.20E-08	5.20E-08	5.20E-08	5.20E-08	5.20E-08	5.20E-08	5.20E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	207.95	244.79	220.07	195.83	213.37	191.82	170.69

Table 20. LCA Results 45 MPa concrete without air GU

Unit		Baseline 45 MPa concrete without air GU/HS 15 FA	45 MPa concrete without air GU/HS	45 MPa concrete without air GU/HS 10 FA	45 MPa concrete without air GU/HS 20 FA	45 MPa concrete without air GUL/HSL	45 MPa concrete without air GUL/HSL 10 FA	45 MPa concrete without air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO2 eq.	418.44	482.49	440.08	396.80	434.01	396.42	358.06
ODP	kg CFC-11 eq.	1.21E-05	1.41E-05	1.28E-05	1.14E-05	1.35E-05	1.22E-05	1.09E-05
EP	kg N eq.	0.70	0.79	0.73	0.67	0.76	0.70	0.64
AP	kg SO2 eq.	1.67	1.87	1.74	1.60	1.72	1.60	1.48
POCP	kg O3 eq.	31.19	34.75	32.40	29.99	31.63	29.58	27.50
Use of primary resources								
RPR _E	MJ, NCV	66.97	74.50	69.51	64.42	86.31	80.15	73.86
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2910.49	3274.23	3033.38	2787.61	2609.74	2434.93	2256.56
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	65.83	77.46	69.76	61.91	70.03	63.07	55.97
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1542.51	1675.39	1587.40	1497.62	1524.00	1451.06	1376.63
ADP _e	kg Sb	2.54E-04	2.63E-04	2.57E-04	2.51E-04	2.62E-04	2.56E-04	2.50E-04
Consumption of freshwater resources								
FW	m ³	1.73	1.80	1.76	1.71	1.75	1.71	1.67
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	32.36	38.07	34.29	30.43	34.37	30.96	27.48
HLRW	m ³	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09	1.14E-09
ILLRW	m ³	5.53E-08	5.53E-08	5.53E-08	5.53E-08	5.53E-08	5.53E-08	5.53E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	203.10	238.97	215.22	190.98	208.30	187.59	166.47

Table 21. LCA Results 45 MPa concrete with air GU

Unit		Baseline 45 MPa concrete with air GU/HS 15 FA	45 MPa concrete with air GU/HS	45 MPa concrete with air GU/HS 10 FA	45 MPa concrete with air GU/HS 20 FA	45 MPa concrete with air GUL/HSL	45 MPa concrete with air GUL/HSL 10 FA	45 MPa concrete with air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO2 eq.	464.66	536.50	488.89	440.43	482.12	439.92	396.96
ODP	kg CFC-11 eq.	1.34E-05	1.57E-05	1.42E-05	1.27E-05	1.50E-05	1.36E-05	1.22E-05
EP	kg N eq.	0.76	0.86	0.80	0.73	0.82	0.76	0.70
AP	kg SO2 eq.	1.82	2.05	1.90	1.74	1.88	1.75	1.61
POCP	kg O3 eq.	33.84	37.83	35.19	32.50	34.33	32.04	29.70
Use of primary resources								
RPR _E	MJ, NCV	76.30	84.74	79.15	73.45	97.99	91.07	84.03
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	3208.09	3616.07	3345.72	3070.47	2870.71	2674.50	2474.72
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	73.85	86.89	78.25	69.45	78.56	70.74	62.79
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADPf	MJ, LHV	1678.35	1827.39	1728.63	1628.08	1657.57	1575.70	1492.34
ADPe	kg Sb	2.98E-04	3.08E-04	3.01E-04	2.95E-04	3.07E-04	3.00E-04	2.94E-04
Consumption of freshwater resources								
FW	m ³	1.69	1.77	1.72	1.67	1.72	1.67	1.62
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	36.29	42.70	38.45	34.13	38.55	34.72	30.82
HLRW	m ³	1.10E-09	1.10E-09	1.10E-09	1.10E-09	1.10E-09	1.10E-09	1.10E-09
ILLRW	m ³	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08	4.99E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	227.82	268.05	241.39	214.25	233.65	210.41	186.75

Table 22. LCA Results 50 MPa concrete with air (C-XL) GU

Unit	Baseline 50 MPa concrete with air (C-XL) GU/HS 15 FA	50 MPa concrete with air (C-XL) GU/HS	50 MPa concrete with air (C-XL) GU/HS 10 FA	50 MPa concrete with air (C-XL) GU/HS 20 FA	50 MPa concrete with air (C-XL) GUL/HSL	50 MPa concrete with air (C-XL) GUL/HSL 10 FA	50 MPa concrete with air (C-XL) GUL/HSL 20 FA	
Environmental impacts								
GWP	kg CO ₂ eq.	473.26	546.83	497.50	449.03	491.08	447.35	404.39
ODP	kg CFC-11 eq.	1.37E-05	1.60E-05	1.45E-05	1.30E-05	1.54E-05	1.39E-05	1.24E-05
EP	kg N eq.	0.76	0.87	0.80	0.73	0.83	0.76	0.70
AP	kg SO ₂ eq.	1.85	2.09	1.93	1.77	1.92	1.77	1.64
POCP	kg O ₃ eq.	34.46	38.55	35.81	33.11	34.96	32.58	30.24
Use of primary resources								
RPR _E	MJ, NCV	73.91	82.56	76.76	71.06	96.14	88.97	81.93
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	3235.58	3653.38	3373.21	3097.95	2889.16	2685.81	2486.03
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	75.73	89.09	80.13	71.33	80.54	72.45	64.49
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1670.96	1823.59	1721.24	1620.68	1649.47	1564.62	1481.26
ADP _e	kg Sb	2.61E-04	2.71E-04	2.64E-04	2.57E-04	2.70E-04	2.63E-04	2.56E-04
Consumption of freshwater resources								
FW	m ³	1.72	1.80	1.74	1.69	1.74	1.69	1.65
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	37.22	43.78	39.38	35.06	39.53	35.56	31.66
HLRW	m ³	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09
ILLRW	m ³	4.70E-08	4.70E-08	4.70E-08	4.70E-08	4.70E-08	4.70E-08	4.70E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO ₂ eq.	233.64	274.84	247.21	220.07	239.56	215.48	191.82

Table 23. LCA Results 50 MPa concrete with air GU

Unit		Baseline 50 MPa concrete with air GU/HS 15 FA	50 MPa concrete with air GU/HS	50 MPa concrete with air GU/HS 10 FA	50 MPa concrete with air GU/HS 20 FA	50 MPa concrete with air GUL/HSL	50 MPa concrete with air GUL/HSL 10 FA	50 MPa concrete with air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO2 eq.	488.29	564.46	514.26	463.20	507.03	462.54	417.27
ODP	kg CFC-11 eq.	1.42E-05	1.66E-05	1.50E-05	1.34E-05	1.59E-05	1.44E-05	1.29E-05
EP	kg N eq.	0.81	0.92	0.84	0.77	0.87	0.81	0.74
AP	kg SO2 eq.	1.91	2.15	1.99	1.83	1.98	1.83	1.69
POCP	kg O3 eq.	35.46	39.69	36.90	34.07	35.99	33.57	31.11
Use of primary resources								
RPR _E	MJ, NCV	76.65	85.61	79.71	73.70	99.59	92.30	84.89
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	3340.24	3772.79	3487.70	3197.69	2985.65	2778.73	2568.25
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	77.93	91.76	82.64	73.37	82.96	74.72	66.34
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1728.54	1886.56	1782.41	1676.47	1707.22	1620.88	1533.06
ADP _e	kg Sb	2.81E-04	2.92E-04	2.85E-04	2.78E-04	2.90E-04	2.83E-04	2.76E-04
Consumption of freshwater resources								
FW	m ³	1.68	1.76	1.71	1.65	1.70	1.66	1.61
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	38.30	45.09	40.61	36.06	40.71	36.67	32.56
HLRW	m ³	1.21E-09	1.21E-09	1.21E-09	1.21E-09	1.21E-09	1.21E-09	1.21E-09
ILLRW	m ³	5.32E-08	5.32E-08	5.32E-08	5.32E-08	5.32E-08	5.32E-08	5.32E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	240.42	283.08	254.97	226.37	246.74	222.24	197.31

Table 24. LCA Results 50 MPa concrete without air GU

Unit		Baseline 50 MPa concrete without air GU/HS 15 FA	50 MPa concrete without air GU/HS	50 MPa concrete without air GU/HS 10 FA	50 MPa concrete without air GU/HS 20 FA	50 MPa concrete without air GUL/HSL	50 MPa concrete without air GUL/HSL 10 FA	50 MPa concrete without air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO ₂ eq.	447.40	516.64	470.77	424.90	464.43	423.77	383.11
ODP	kg CFC-11 eq.	1.30E-05	1.51E-05	1.37E-05	1.22E-05	1.45E-05	1.31E-05	1.17E-05
EP	kg N eq.	0.74	0.84	0.77	0.71	0.80	0.74	0.68
AP	kg SO ₂ eq.	1.77	1.99	1.84	1.70	1.83	1.70	1.57
POCP	kg O ₃ eq.	32.99	36.84	34.29	31.74	33.48	31.26	29.05
Use of primary resources								
RPR _E	MJ, NCV	71.47	79.61	74.22	68.83	92.33	85.67	79.01
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	3091.31	3484.53	3224.02	2963.51	2768.83	2579.75	2390.67
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	70.86	83.43	75.10	66.78	75.43	67.90	60.37
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	1622.18	1765.83	1670.66	1575.49	1602.77	1523.87	1444.98
ADP _e	kg Sb	2.70E-04	2.80E-04	2.73E-04	2.67E-04	2.78E-04	2.72E-04	2.66E-04
Consumption of freshwater resources								
FW	m ³	1.74	1.81	1.77	1.72	1.76	1.72	1.68
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	34.83	41.00	36.91	32.82	37.02	33.33	29.64
HLRW	m ³	1.13E-09	1.13E-09	1.13E-09	1.13E-09	1.13E-09	1.13E-09	1.13E-09
ILLRW	m ³	5.37E-08	5.37E-08	5.37E-08	5.37E-08	5.37E-08	5.37E-08	5.37E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO ₂ eq.	218.61	257.39	231.70	206.01	224.35	201.96	179.57

Table 25. LCA Results 55 MPa concrete without air GU

Unit		Baseline 55 MPa concrete without air GU/HS 15 FA	55 MPa concrete without air GU/HS	55 MPa concrete without air GU/HS 10 FA	55 MPa concrete without air GU/HS 20 FA	55 MPa concrete without air GUL/HSL	55 MPa concrete without air GUL/HSL 10 FA	55 MPa concrete without air GUL/HSL 20 FA
Environmental impacts								
GWP	kg CO2 eq.	466.27	538.11	490.54	442.04	483.54	441.38	398.38
ODP	kg CFC-11 eq.	1.35E-05	1.58E-05	1.43E-05	1.27E-05	1.51E-05	1.37E-05	1.22E-05
EP	kg N eq.	0.76	0.86	0.80	0.73	0.82	0.76	0.70
AP	kg SO2 eq.	1.83	2.06	1.91	1.75	1.89	1.76	1.62
POCP	kg O3 eq.	34.05	38.04	35.40	32.70	34.52	32.24	29.89
Use of primary resources								
RPRE	MJ, NCV	75.84	84.29	78.69	72.99	97.58	90.67	83.63
RPRM	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPRE	MJ, NCV	3214.13	3622.10	3352.26	3076.50	2874.05	2678.34	2478.06
NRPRM	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Use of secondary resources								
SM	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	74.16	87.20	78.56	69.76	78.84	71.03	63.07
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADPf	MJ, LHV	1678.56	1827.60	1729.31	1628.28	1657.16	1575.77	1491.93
ADPe	kg Sb	2.94E-04	3.04E-04	2.97E-04	2.90E-04	3.02E-04	2.96E-04	2.89E-04
Consumption of freshwater resources								
FW	m ³	1.72	1.80	1.75	1.70	1.74	1.70	1.65
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	36.45	42.85	38.61	34.29	38.69	34.86	30.96
HLRW	m ³	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09	1.07E-09
ILLRW	m ³	5.05E-08	5.05E-08	5.05E-08	5.05E-08	5.05E-08	5.05E-08	5.05E-08
CRU	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MR	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency								
CCE	kg CO2 eq.	228.79	269.02	242.36	215.22	234.49	211.25	187.59

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