

Environmental Product Declaration



Ready Mixed Concrete
Association of Ontario

Concrete Ontario Member Industry-Wide EPD for **READY-MIXED CONCRETE**




Pier 27, Toronto, Ontario

Architect: architectsAlliance

Owner: Cityzen Development Group and
Fernbrook Homes

ASTM International Certified Environmental Product Declaration

Declared Product	This Environmental Product Declaration (EPD) covers concrete mixes produced by Concrete Ontario members.	
Declaration Owner	Concrete Ontario 1 Prologis Boulevard, Suite 102B Mississauga, Ontario L5W 0G2 Phone: 905-564-2726 Website: www.rmcao.org	 CONCRETE ONTARIO Ready Mixed Concrete Association of Ontario
Program Operator	ASTM International 100 Bar Harbor Drive West Conshohocken, PA 19428-2959, USA Website: www.astm.org	 ASTM INTERNATIONAL Helping our world work better
LCA and EPD Developer	Athena Sustainable Materials Institute 280 Albert Street, Suite 404 Ottawa, ON K1P 5G8, Canada Website: www.athenasmi.org	 Athena Sustainable Materials Institute
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 351	
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/slag cement, 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 Canada. Key product variables include:

- **28-day strength** – Different compressive strengths were considered, ranging between 20 MPa and 70 MPa.
- **Slag cement** – Varies between 0% and 50%;
- **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), slag cement, fly ash, silica fume, 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 Ontario as having participated in the study. The scope of this EPD is cradle-to-gate and considers the following life cycle stages.

- **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-lifestage				
Raw Material supply	Transport	Manufacturing	Transport	Construction/Installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	De-Construction/Transport	Waste processing	Disposal		
															A1	A2

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 in Ontario. For each specified mix, variations were developed based on the use of GU and GUL cement as well as different SCM replacement levels. For each mix, a “baseline” mix was developed that represents the average product mix within Ontario. 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. Portland cement, also known as Type I or General Use cement is labeled as “GU”. Portland limestone cement, also known as Type IL or General Use Limestone cement is labeled as “GUL”. The name of the mix also notes whether it is “air entrained” and 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 classes see CSA standard A23.1.

SCM Replacement: Identify the supplementary cementing material (SCM) percentage. Slag Cement is labeled in the mix designs as “SL”, and silica fume blended cement is labeled as “GUBSF”. For example, a mix with 25% slag cement is denoted in the mix design identifier as “25 SL”.

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:

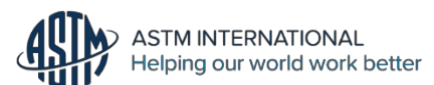
- Allocation was not applied to any of the gate-to-gate production facilities. For facilities that manufacture additional products (i.e. aggregate), the LCI flows at the facility specific to the concrete production were reported.
- For secondary data sources, the NSF PCR default allocation selection (i.e. “Cut-off” or “Alloc Rec”) was applied.
- The product category rules for this EPD recognize fly ash, silica fume and slag 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 Ontario (Concrete Ontario). 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 Ontario and a list of certified concrete plants can be found on the Association website (www.rmcao.org).



Ready Mixed Concrete
Association of Ontario



Data Sources and Software

This EPD is based on foreground LCI data collected from the participating companies' production facilities. A representative sample of Concrete Ontario member facilities were selected based on technical attributes, production scale, and geographic location. In total, 80 facilities operated by Concrete Ontario member companies completed LCI data collection questionnaires representing over 30% of all Concrete Ontario 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 2 to 4 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 Ontario.

Table 2. A1 - Raw Material Supply				
Materials	LCI Data Source	Geography	Year	Data Quality Assessment
General Use Cement ASTM C150, C595, C1157 CSAA3000	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 CSAA3000	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 CSAA3000	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 CSAA3000	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 <i>coarse and fine</i> ASTM C33 CSAA23.1/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 <i>coarse and fine</i> ASTM C30 CSAA23.1/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	FFCA EPDs for Air Entrainers, Plasticizers and superplasticizers (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 CSAA23.1/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

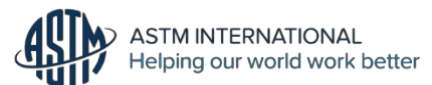
Table 3. A2 - Transportation

Process	LCI Data Source	Geography	Year	Data Quality Assessment
TruckTransportation	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
RailTransportation	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
OceanTransportation	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 4. A3 - Manufacturing

Process	LCI Data Source	Geography	Year	Data Quality Assessment
Electricity	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-HazardousWaste	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 5. The Impact Assessment method and other calculation methodologies are specified in Table 5. Tables 6 through 28 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 5. Life Cycle Category Indicators and Inventory Metrics

Core Mandatory Impact Indicator	Abbreviation	Unit	Method/Source
Global warming potential	GWP	kg CO ₂ e	TRACI 2.1 V1.02
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11e	TRACI 2.1 V1.02
Acidification potential of soil and water sources	AP	kg SO ₂ e	TRACI 2.1 V1.02
Eutrophication potential	EP	kg Ne	TRACI 2.1 V1.02
Photochemical smog creation potential	POCP	kg O ₃ e	TRACI 2.1 V1.02
Abiotic depletion potential (ADP _{fossil})*	ADP _f	MJ, NCV	CML-IA Baseline V3.02
Abiotic depletion potential (ADP _{elements})*	ADP _e	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 5. 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 6. LCA Results 20 MPa concrete without air

Unit	Baseline 20MPa concrete without air GU 10 SL	20 MPa concrete without air GU	20 MPa concrete without air GU 15 SL	20 MPa concrete without air GU 25 SL	20 MPa concrete without air GU 35 SL	20 MPa concrete without air GU 50 SL	20 MPa concrete without air GUL	20 MPa concrete without air GUL 15 SL	20 MPa concrete without air GUL 25 SL	20 MPa concrete without air GUL 35 SL	20 MPa concrete without air GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	220.29	236.90	211.99	195.38	178.77	153.85	221.84	199.19	184.08	168.98	146.32
ODP	kg CFC-11 eq.	5.46E-06	5.38E-06	5.50E-06	5.58E-06	5.66E-06	5.78E-06	5.15E-06	5.31E-06	5.41E-06	5.51E-06	5.66E-06
EP	kg N eq.	0.17	0.18	0.17	0.16	0.15	0.14	0.17	0.16	0.15	0.15	0.14
AP	kg SO ₂ eq.	1.09	1.12	1.08	1.05	1.02	0.99	1.06	1.03	1.01	0.99	0.96
POCP	kg O ₃ eq.	18.99	19.12	18.93	18.80	18.67	18.48	18.43	18.34	18.28	18.22	18.13
Use of primary resources												
RPR _E	MJ, NCV	63.92	67.78	61.99	58.13	54.27	48.49	67.60	61.84	58.00	54.16	48.40
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1450.79	1481.54	1435.42	1404.67	1373.93	1327.81	1412.35	1376.61	1352.79	1328.96	1293.22
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	97.68	108.53	92.25	81.40	70.54	54.26	100.88	85.74	75.66	65.57	50.44
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	574.04	572.34	574.90	576.60	578.31	580.87	568.63	571.75	573.83	575.90	579.02
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.41	2.45	2.39	2.35	2.30	2.24	2.43	2.37	2.33	2.29	2.23
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	177.24	196.92	167.39	147.70	128.02	98.48	186.18	158.26	139.64	121.03	93.11
HLRW	m ³	3.42E-07	3.42E-07	3.42E-07	3.42E-07	3.42E-07	3.42E-07	3.42E-07	3.42E-07	3.42E-07	3.42E-07	3.42E-07
ILLRW	m ³	2.96E-07	2.96E-07	2.96E-07	2.96E-07	2.96E-07	2.96E-07	2.96E-07	2.96E-07	2.96E-07	2.96E-07	2.96E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	100.33	111.48	94.76	83.61	72.46	55.74	102.91	87.48	77.19	66.89	51.46

Table 7. LCA Results 25 MPa concrete without air

Unit	Baseline 25MPa concrete without air GU 10 SL	25 MPa concrete without air GU	25 MPa concrete without air GU 15 SL	25 MPa concrete without air GU 25 SL	25 MPa concrete without air GU 35 SL	25 MPa concrete without air GU 50 SL	25 MPa concrete without air GUL	25 MPa concrete without air GUL 15 SL	25 MPa concrete without air GUL 25 SL	25 MPa concrete without air GUL 35 SL	25 MPa concrete without air GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	254.05	273.67	244.24	224.62	205.01	175.58	255.89	229.13	211.29	193.45	166.69
ODP	kg CFC-11 eq.	6.35E-06	6.25E-06	6.40E-06	6.49E-06	6.58E-06	6.72E-06	5.98E-06	6.16E-06	6.28E-06	6.41E-06	6.59E-06
EP	kg N eq.	0.20	0.21	0.19	0.19	0.18	0.16	0.19	0.18	0.18	0.17	0.16
AP	kg SO ₂ eq.	1.22	1.25	1.21	1.18	1.15	1.10	1.19	1.16	1.13	1.11	1.07
POCP	kg O ₃ eq.	20.96	21.11	20.88	20.73	20.58	20.35	20.30	20.19	20.12	20.05	19.94
Use of primary resources												
RPR _E	MJ, NCV	72.27	76.83	69.99	65.43	60.88	54.04	76.62	69.82	65.28	60.74	53.94
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1600.80	1637.11	1582.64	1546.33	1510.02	1455.55	1555.40	1513.19	1485.05	1456.91	1414.69
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	115.37	128.18	108.96	96.14	83.32	64.09	119.14	101.27	89.36	77.44	59.57
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADP _f	MJ, LHV	587.66	585.65	588.67	590.69	592.71	595.73	581.27	584.95	587.41	589.86	593.54
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.47	2.52	2.45	2.40	2.35	2.28	2.50	2.43	2.38	2.33	2.27
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	209.33	232.58	197.70	174.45	151.19	116.31	219.89	186.91	164.93	142.94	109.97
HLRW	m ³	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07
ILLRW	m ³	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	118.50	131.67	111.92	98.75	85.59	65.83	121.55	103.32	91.16	79.01	60.78

Table 8. LCA Results 25 MPa concrete without air & 0.55 w/cm (N-CF)

Unit	Baseline 25 MPa concrete without air & 0.55 w/cm (N-CF) GU 10 SL	25 MPa concrete without air & 0.55 w/cm (N-CF) GU	25 MPa concrete without air & 0.55 w/cm (N-CF) GU 15 SL	25 MPa concrete without air & 0.55 w/cm (N-CF) GU 25 SL	25 MPa concrete without air & 0.55 w/cm (N-CF) GU 35 SL	25 MPa concrete without air & 0.55 w/cm (N-CF) GUL	25 MPa concrete without air & 0.55 w/cm (N-CF) GUL 15 SL	25 MPa concrete without air & 0.55 w/cm (N-CF) GUL 25 SL	25 MPa concrete without air & 0.55 w/cm (N-CF) GUL 35 SL	
Environmental impacts										
GWP	kg CO ₂ eq.	264.94	285.45	254.69	234.17	213.66	266.86	238.88	220.23	201.58
ODP	kg CFC-11 eq.	6.61E-06	6.51E-06	6.66E-06	6.76E-06	6.86E-06	6.23E-06	6.42E-06	6.55E-06	6.67E-06
EP	kg N eq.	0.21	0.22	0.20	0.19	0.18	0.20	0.19	0.18	0.18
AP	kg SO ₂ eq.	1.27	1.30	1.25	1.22	1.19	1.23	1.20	1.17	1.14
POCP	kg O ₃ eq.	21.57	21.73	21.49	21.33	21.17	20.88	20.77	20.69	20.62
Use of primary resources										
RPR _E	MJ, NCV	76.86	81.63	74.48	69.72	64.95	81.41	74.30	69.56	64.81
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1664.35	1702.32	1645.37	1607.40	1569.43	1616.89	1572.75	1543.32	1513.90
NRPR _M	MJ, NCV	0.00	0.00	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	0.00	0.00
RSF	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	120.62	134.03	113.92	100.52	87.12	124.57	105.89	93.43	80.97
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential										
ADP _f	MJ, LHV	609.39	607.28	610.44	612.55	614.66	602.71	606.56	609.12	611.69
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources										
FW	m ³	2.49	2.55	2.47	2.42	2.37	2.52	2.45	2.40	2.35
Waste and output flows										
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	218.87	243.18	206.71	182.40	158.08	229.91	195.43	172.44	149.46
HLRW	m ³	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07	3.41E-07
ILLRW	m ³	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07	2.95E-07
CRU	kg	0.00	0.00	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	0.00	0.00
MER	kg	0.00	0.00	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	0.00	0.00
Additional inventory parameters for transparency										
CCE	kg CO ₂ eq.	123.58	137.67	117.02	103.25	89.49	127.09	108.03	95.32	82.61

Table 9. LCA Results 30 MPa concrete without air

Unit	Baseline 30MPa concrete without air GU 15 SL	30 MPa concrete without air GU	30 MPa concrete without air GU 15 SL	30 MPa concrete without air GU 25 SL	30 MPa concrete without air GU 35 SL	30 MPa concrete without air GU 50 SL	30 MPa concrete without air GUL	30 MPa concrete without air GUL 15 SL	30 MPa concrete without air GUL 25 SL	30 MPa concrete without air GUL 35 SL	30 MPa concrete without air GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	264.38	296.62	264.38	242.88	221.39	189.14	277.14	247.82	228.27	208.72	179.40
ODP	kg CFC-11 eq.	6.95E-06	6.80E-06	6.95E-06	7.06E-06	7.16E-06	7.31E-06	6.50E-06	6.70E-06	6.83E-06	6.96E-06	7.16E-06
EP	kg N eq.	0.21	0.22	0.21	0.20	0.19	0.18	0.21	0.20	0.19	0.18	0.17
AP	kg SO ₂ eq.	1.29	1.34	1.29	1.26	1.22	1.17	1.27	1.23	1.21	1.18	1.14
POCP	kg O ₃ eq.	22.12	22.37	22.12	21.96	21.79	21.54	21.48	21.36	21.28	21.21	21.09
Use of primary resources												
RPR _E	MJ, NCV	74.83	82.32	74.83	69.84	64.85	57.36	82.10	74.64	69.67	64.70	57.25
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1674.23	1733.91	1674.23	1634.45	1594.66	1534.98	1644.38	1598.13	1567.30	1536.46	1490.21
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	119.38	140.45	119.38	105.34	91.29	70.22	130.54	110.96	97.91	84.85	65.27
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADP _f	MJ, LHV	596.92	593.60	596.92	599.13	601.33	604.65	588.81	592.84	595.53	598.22	602.25
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.49	2.56	2.49	2.43	2.38	2.30	2.54	2.46	2.41	2.36	2.29
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	216.61	254.83	216.61	191.14	165.66	127.44	240.92	204.79	180.71	156.62	120.49
HLRW	m ³	3.40E-07	3.40E-07	3.40E-07	3.40E-07	3.40E-07	3.40E-07	3.40E-07	3.40E-07	3.40E-07	3.40E-07	3.40E-07
ILLRW	m ³	2.94E-07	2.94E-07	2.94E-07	2.94E-07	2.94E-07	2.94E-07	2.94E-07	2.94E-07	2.94E-07	2.94E-07	2.94E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	122.63	144.27	122.63	108.20	93.77	72.13	133.18	113.20	99.89	86.57	66.59

Table 10. LCA Results 35 MPa concrete without air

Unit	Baseline 35MPa concrete without air GU 15 SL	35 MPa concrete without air GU	35 MPa concrete without air GU 15 SL	35 MPa concrete without air GU 25 SL	35 MPa concrete without air GU 35 SL	35 MPa concrete without air GU 50 SL	35 MPa concrete without air GUL	35 MPa concrete without air GUL 15 SL	35 MPa concrete without air GUL 25 SL	35 MPa concrete without air GUL 35 SL	35 MPa concrete without air GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	295.46	332.01	295.46	271.10	246.73	210.18	309.93	276.69	254.53	232.37	199.14
ODP	kg CFC-11 eq.	7.81E-06	7.63E-06	7.81E-06	7.92E-06	8.04E-06	8.21E-06	7.29E-06	7.52E-06	7.67E-06	7.82E-06	8.04E-06
EP	kg N eq.	0.23	0.25	0.23	0.22	0.21	0.20	0.24	0.22	0.21	0.20	0.19
AP	kg SO ₂ eq.	1.42	1.47	1.42	1.38	1.34	1.28	1.40	1.35	1.32	1.29	1.24
POCP	kg O ₃ eq.	23.98	24.27	23.98	23.79	23.60	23.32	23.25	23.12	23.03	22.94	22.81
Use of primary resources												
RPR _E	MJ, NCV	83.34	91.83	83.34	77.68	72.02	63.53	91.57	83.12	77.49	71.85	63.40
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1821.63	1889.29	1821.63	1776.53	1731.42	1663.77	1787.79	1735.36	1700.41	1665.45	1613.02
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	135.33	159.22	135.33	119.41	103.49	79.61	147.99	125.79	110.99	96.19	73.99
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPf	MJ, LHV	616.51	612.76	616.51	619.02	621.52	625.28	607.32	611.89	614.94	617.99	622.56
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.54	2.63	2.54	2.48	2.42	2.33	2.60	2.51	2.46	2.40	2.31
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	245.55	288.87	245.55	216.67	187.79	144.46	273.11	232.15	204.85	177.54	136.58
HLRW	m ³	3.39E-07	3.39E-07	3.39E-07	3.39E-07	3.39E-07	3.39E-07	3.39E-07	3.39E-07	3.39E-07	3.39E-07	3.39E-07
ILLRW	m ³	2.92E-07	2.92E-07	2.92E-07	2.92E-07	2.92E-07	2.92E-07	2.92E-07	2.92E-07	2.92E-07	2.92E-07	2.92E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	139.01	163.54	139.01	122.66	106.30	81.77	150.98	128.33	113.23	98.13	75.49

Table 11. LCA Results 40 MPa concrete without air

Unit		Baseline 40MPa concrete without air GU 15 SL	40 MPa concrete without air GU	40 MPa concrete without air GU 15 SL	40 MPa concrete without air 25 SL	40 MPa concrete without air 35 SL	40 MPa concrete without air 50 SL	40 MPa concrete without air GUL	40 MPa concrete without air GUL 15 SL	40 MPa concrete without air GUL 25 SL	40 MPa concrete without air GUL 35 SL	40 MPa concrete without air GUL 50 SL
Environmental impacts												
GWP	kg CO ₂ eq.	326.25	367.02	326.25	299.07	271.89	231.13	342.39	305.31	280.60	255.88	218.81
ODP	kg CFC-11 eq.	8.64E-06	8.44E-06	8.64E-06	8.77E-06	8.90E-06	9.09E-06	8.06E-06	8.32E-06	8.48E-06	8.65E-06	8.90E-06
EP	kg N eq.	0.26	0.28	0.26	0.25	0.23	0.22	0.26	0.24	0.23	0.22	0.21
AP	kg SO ₂ eq.	1.54	1.60	1.54	1.50	1.45	1.39	1.52	1.47	1.43	1.40	1.35
POCP	kg O ₃ eq.	25.74	26.06	25.74	25.53	25.32	25.00	24.93	24.78	24.68	24.59	24.44
Use of primary resources												
RPR _e	MJ, NCV	93.10	102.57	93.10	86.79	80.48	71.01	102.29	92.86	86.58	80.29	70.87
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _e	MJ, NCV	1975.27	2050.74	1975.27	1924.97	1874.66	1799.19	1937.53	1879.05	1840.06	1801.07	1742.59
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	150.95	177.59	150.95	133.20	115.44	88.80	165.07	140.31	123.80	107.29	82.53
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADP _f	MJ, LHV	644.57	640.38	644.57	647.36	650.16	654.35	634.32	639.42	642.82	646.22	651.32
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.58	2.68	2.58	2.52	2.45	2.35	2.65	2.55	2.49	2.43	2.33
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	273.89	322.22	273.89	241.68	209.46	161.13	304.63	258.94	228.49	198.03	152.34
HLRW	m ³	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07
ILLRW	m ³	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	155.06	182.42	155.06	136.82	118.57	91.21	168.40	143.14	126.30	109.46	84.20

Table 12. LCA Results 45 MPa concrete without air

Unit	Baseline 45MPa concrete without air GU 15 SL	45 MPa concrete	45 MPa concrete	45 MPa concrete	45 MPa concrete	45 MPa concrete	45 MPa concrete	45 MPa concrete	45 MPa concrete	45 MPa concrete	45 MPa concrete	45 MPa concrete
		without air GU	without air GU 15 SL	without air GU 25 SL	without air GU 35 SL	without air GU 50 SL	without air GUL	without air GUL 15 SL	without air GUL 25 SL	without air GUL 35 SL	without air GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	349.88	394.05	349.88	320.44	290.99	246.83	367.36	327.20	300.42	273.65	233.48
ODP	kg CFC-11 eq.	9.31E-06	9.10E-06	9.31E-06	9.45E-06	9.59E-06	9.80E-06	8.69E-06	8.96E-06	9.15E-06	9.33E-06	9.60E-06
EP	kg N eq.	0.28	0.30	0.28	0.26	0.25	0.23	0.28	0.26	0.25	0.24	0.22
AP	kg SO ₂ eq.	1.64	1.70	1.64	1.59	1.54	1.47	1.61	1.56	1.52	1.48	1.43
POCP	kg O ₃ eq.	27.25	27.59	27.25	27.02	26.79	26.45	26.37	26.21	26.10	25.99	25.83
Use of primary resources												
RPR _E	MJ, NCV	97.06	107.32	97.06	90.22	83.38	73.12	107.01	96.80	89.99	83.18	72.97
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2070.32	2152.07	2070.32	2015.82	1961.32	1879.56	2029.43	1966.07	1923.84	1881.60	1818.24
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	163.53	192.39	163.53	144.29	125.06	96.20	178.82	152.00	134.12	116.24	89.41
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPF	MJ, LHV	639.97	635.43	639.97	643.00	646.02	650.56	628.86	634.39	638.07	641.75	647.28
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.63	2.74	2.63	2.56	2.49	2.38	2.70	2.60	2.53	2.46	2.36
Waste and output flows												
HWD	kg	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	296.71	349.06	296.71	261.81	226.91	174.56	330.01	280.52	247.52	214.53	165.03
HLRW	m ³	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07	3.36E-07
ILLRW	m ³	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07	2.89E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	167.98	197.62	167.98	148.22	128.46	98.81	182.44	155.07	136.83	118.58	91.22

Table 13. LCA Results 50 MPa concrete without air GUbSF

	Unit	Baseline 50MPa concrete without air GUbSF 20 SL	50 MPa concrete without air GUbSF	50 MPa concrete without air GUbSF 15 SL	50 MPa concrete without air GUbSF 25 SL	50 MPa concrete without air GUbSF 35 SL	50 MPa concrete without air GUbSF 50 SL
Environmental impacts							
GWP	kg CO ₂ eq.	335.76	393.19	350.12	321.41	292.69	249.62
ODP	kg CFC-11 eq.	9.50E-06	9.04E-06	9.38E-06	9.61E-06	9.83E-06	1.02E-05
EP	kg N eq.	0.27	0.30	0.28	0.27	0.26	0.24
AP	kg SO ₂ eq.	1.63	1.70	1.65	1.61	1.57	1.51
POCP	kg O ₃ eq.	27.42	27.60	27.46	27.37	27.28	27.15
Use of primary resources							
RPR _E	MJ, NCV	96.41	109.60	99.71	93.11	86.51	76.61
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2080.35	2172.34	2103.35	2057.35	2011.35	1942.36
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	152.92	191.15	162.48	143.36	124.25	95.58
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential							
ADP _f	MJ, LHV	671.21	663.04	669.17	673.26	677.34	683.47
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources							
FW	m ³	2.59	2.73	2.62	2.55	2.48	2.37
Waste and output flows							
HWD	kg	0.02	0.03	0.02	0.02	0.02	0.02
NHWD	kg	277.46	346.81	294.80	260.12	225.45	173.43
HLRW	m3	3.35E-07	3.35E-07	3.35E-07	3.35E-07	3.35E-07	3.35E-07
ILLRW	m3	2.88E-07	2.88E-07	2.88E-07	2.88E-07	2.88E-07	2.88E-07
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 CO ₂ eq.	157.08	196.35	166.90	147.26	127.63	98.17

Table 14. LCA Results 55 MPa concrete without air GUBSF

Unit		Baseline 55 MPa concrete without air GUBSF 20 SL	55 MPa concrete without air GUBSF	55 MPa concrete without air GUBSF 15 SL	55 MPa concrete without air GUBSF 25 SL	55 MPa concrete without air GUBSF 35 SL	55 MPa concrete without air GUBSF 50 SL
Environmental impacts							
GWP	kg CO ₂ eq.	354.67	415.62	369.91	339.43	308.95	263.23
ODP	kg CFC-11 eq.	1.00E-05	9.56E-06	9.92E-06	1.02E-05	1.04E-05	1.08E-05
EP	kg N eq.	0.29	0.31	0.29	0.28	0.27	0.25
AP	kg SO ₂ eq.	1.71	1.79	1.73	1.68	1.64	1.58
POCP	kg O ₃ eq.	28.57	28.76	28.62	28.52	28.43	28.28
Use of primary resources							
RPR _E	MJ, NCV	102.50	116.51	106.01	99.00	92.00	81.49
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2178.77	2276.42	2203.18	2154.36	2105.54	2032.30
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	162.32	202.90	172.46	152.17	131.88	101.45
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential							
ADP _f	MJ, LHV	690.23	681.55	688.06	692.40	696.73	703.24
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources							
FW	m ³	2.62	2.77	2.66	2.58	2.51	2.39
Waste and output flows							
HWD	kg	0.02	0.03	0.02	0.02	0.02	0.02
NHWD	kg	294.51	368.12	312.91	276.11	239.30	184.09
HLRW	m ³	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07
ILLRW	m ³	2.86E-07	2.86E-07	2.86E-07	2.86E-07	2.86E-07	2.86E-07
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 CO ₂ eq.	166.73	208.41	177.15	156.31	135.47	104.21

Table 15. LCA Results 60 MPa concrete without air GUbSF

Unit		Baseline 60MPa concrete without air GUbSF 20 SL	60 MPa concrete without air GUbSF	60 MPa concrete without air GUbSF 15 SL	60 MPa concrete without air GUbSF 25 SL	60 MPa concrete without air GUbSF 35 SL	60 MPa concrete without air GUbSF 50 SL
Environmental impacts							
GWP	kg CO ₂ eq.	361.25	423.49	376.81	345.69	314.57	267.89
ODP	kg CFC-11 eq.	1.02E-05	9.75E-06	1.01E-05	1.04E-05	1.06E-05	1.10E-05
EP	kg N eq.	0.29	0.32	0.30	0.29	0.27	0.26
AP	kg SO ₂ eq.	1.73	1.81	1.75	1.71	1.67	1.61
POCP	kg O ₃ eq.	28.91	29.10	28.96	28.86	28.76	28.62
Use of primary resources							
RPR _E	MJ, NCV	104.62	118.92	108.19	101.04	93.89	83.16
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2209.90	2309.60	2234.83	2184.98	2135.13	2060.35
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	165.74	207.17	176.09	155.38	134.66	103.58
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential							
ADPf	MJ, LHV	693.04	684.18	690.83	695.26	699.69	706.33
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources							
FW	m ³	2.61	2.77	2.65	2.57	2.50	2.38
Waste and output flows							
HWD	kg	0.02	0.03	0.02	0.02	0.02	0.02
NHWD	kg	300.71	375.87	319.50	281.92	244.34	187.96
HLRW	m3	3.32E-07	3.32E-07	3.32E-07	3.32E-07	3.32E-07	3.32E-07
ILLRW	m3	2.84E-07	2.84E-07	2.84E-07	2.84E-07	2.84E-07	2.84E-07
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 CO ₂ eq.	170.24	212.80	180.88	159.60	138.32	106.40

Table 16. LCA Results 70MPa concrete without air GUbSF

Unit	Baseline 70MPa concrete without air GUbSF 25 SL	70 MPa concrete without air GUbSF	70 MPa concrete without air GUbSF 15 SL	70 MPa concrete without air GUbSF 25 SL	70 MPa concrete without air GUbSF 35 SL	70 MPa concrete without air GUbSF 50 SL	
Environmental impacts							
GWP	kg CO ₂ eq.	354.42	434.63	386.50	354.42	322.34	274.22
ODP	kg CFC-11 eq.	1.07E-05	1.00E-05	1.04E-05	1.07E-05	1.09E-05	1.13E-05
EP	kg N eq.	0.29	0.33	0.31	0.29	0.28	0.26
AP	kg SO ₂ eq.	1.75	1.86	1.79	1.75	1.71	1.64
POCP	kg O ₃ eq.	29.55	29.80	29.65	29.55	29.45	29.30
Use of primary resources							
RPR _E	MJ, NCV	100.69	119.12	108.06	100.69	93.32	82.26
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2211.15	2339.63	2262.54	2211.15	2159.76	2082.67
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	160.18	213.58	181.54	160.18	138.82	106.79
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential							
ADP _f	MJ, LHV	680.36	668.94	675.79	680.36	684.93	691.78
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources							
FW	m ³	2.60	2.80	2.68	2.60	2.52	2.40
Waste and output flows							
HWD	kg	0.02	0.03	0.03	0.02	0.02	0.02
NHWD	kg	290.64	387.49	329.38	290.64	251.89	193.78
HLRW	m3	3.32E-07	3.32E-07	3.32E-07	3.32E-07	3.32E-07	3.32E-07
ILLRW	m3	2.84E-07	2.84E-07	2.84E-07	2.84E-07	2.84E-07	2.84E-07
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 CO ₂ eq.	164.54	219.38	186.48	164.54	142.60	109.69

Table 17. LCA Results 20 MPa concrete with air & 0.70 w/cm

Unit	Baseline	20 MPa	20 MPa concrete	20 MPa concrete	20 MPa concrete	20 MPa concrete	20 MPa concrete	20 MPa concrete	20 MPa concrete	20 MPa concrete	20 MPa concrete	20 MPa concrete
	concrete with air & 0.70 w/cm GU 10 SL	concrete with air & 0.70 w/cm GU	with air & 0.70 w/cm GU 15 SL	with air & 0.70 w/cm GU 25 SL	with air & 0.70 w/cm GU 35 SL	with air & 0.70 w/cm GU 50 SL	with air & 0.70 w/cm GUL	with air & 0.70 w/cm GUL	with air & 0.70 w/cm GUL	with air & 0.70 w/cm GUL	with air & 0.70 w/cm GUL	with air & 0.70 w/cm GUL
Environmental impacts												
GWP	kg CO ₂ eq.	227.16	244.44	218.53	201.25	183.97	158.05	228.78	205.21	189.50	173.79	150.22
ODP	kg CFC-11 eq.	5.65E-06	5.57E-06	5.69E-06	5.77E-06	5.85E-06	5.98E-06	5.32E-06	5.48E-06	5.59E-06	5.70E-06	5.86E-06
EP	kg N eq.	0.18	0.18	0.17	0.17	0.16	0.15	0.17	0.16	0.16	0.15	0.14
AP	kg SO ₂ eq.	1.11	1.14	1.10	1.07	1.04	1.00	1.08	1.05	1.03	1.01	0.98
POCP	kg O ₃ eq.	19.23	19.37	19.16	19.03	18.90	18.69	18.65	18.55	18.49	18.43	18.33
Use of primary resources												
RPR _e	MJ, NCV	65.76	69.78	63.76	59.74	55.73	49.71	69.60	63.60	59.61	55.61	49.62
RPR _m	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _e	MJ, NCV	1474.29	1506.27	1458.30	1426.32	1394.33	1346.36	1434.30	1397.12	1372.34	1347.55	1310.37
NRPR _m	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	101.61	112.90	95.97	84.68	73.39	56.45	104.94	89.20	78.70	68.21	52.47
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPF	MJ, LHV	568.72	566.94	569.60	571.38	573.16	575.82	563.09	566.33	568.49	570.65	573.89
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.39	2.43	2.37	2.32	2.28	2.22	2.41	2.35	2.31	2.27	2.21
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	184.37	204.85	174.13	153.65	133.17	102.45	193.68	164.63	145.27	125.91	96.86
HLRW	m ³	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07
ILLRW	m ³	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	104.37	115.97	98.58	86.98	75.38	57.99	107.06	91.00	80.29	69.59	53.53

Table 18. LCA Results 25 MPa concrete with air & 0.55 w/cm (F-2)

Unit	Baseline 25MPa concrete with air & 0.55 w/cm (F-2) GU 10 SL	25 MPa concrete with air & 0.55 w/cm (F-2) GU	25 MPa concrete with air & 0.55 w/cm (F-2) GU 15 SL	25 MPa concrete with air & 0.55 w/cm (F-2) GU 25 SL	25 MPa concrete with air & 0.55 w/cm (F-2) GU 35 SL	25 MPa concrete with air & 0.55 w/cm (F-2) GU 50 SL	25 MPa concrete with air & 0.55 w/cm (F-2) GUL	25 MPa concrete with air & 0.55 w/cm (F-2) GUL 15 SL	25 MPa concrete with air & 0.55 w/cm (F-2) GUL 25 SL	25 MPa concrete with air & 0.55 w/cm (F-2) GUL 35 SL	25 MPa concrete with air & 0.55 w/cm (F-2) GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	260.64	280.89	250.51	230.26	210.01	179.63	262.53	234.91	216.50	198.08	170.46
ODP	kg CFC-11 eq.	6.52E-06	6.43E-06	6.57E-06	6.67E-06	6.77E-06	6.91E-06	6.15E-06	6.33E-06	6.46E-06	6.58E-06	6.77E-06
EP	kg N eq.	0.20	0.21	0.20	0.19	0.18	0.17	0.20	0.19	0.18	0.17	0.16
AP	kg SO ₂ eq.	1.24	1.28	1.23	1.20	1.16	1.12	1.21	1.17	1.15	1.12	1.09
POCP	kg O ₃ eq.	21.20	21.36	21.12	20.97	20.81	20.57	20.52	20.41	20.33	20.26	20.15
Use of primary resources												
RPR _E	MJ, NCV	74.10	78.81	71.75	67.05	62.34	55.29	78.60	71.57	66.89	62.21	55.18
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1624.72	1662.20	1605.97	1568.49	1531.00	1474.77	1577.85	1534.28	1505.22	1476.17	1432.60
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	119.09	132.32	112.48	99.24	86.01	66.16	122.99	104.54	92.24	79.95	61.50
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPF	MJ, LHV	583.91	581.83	584.95	587.03	589.11	592.23	577.31	581.11	583.64	586.18	589.98
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.45	2.50	2.42	2.37	2.32	2.25	2.47	2.40	2.35	2.31	2.23
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	216.09	240.09	204.08	180.08	156.08	120.07	226.99	192.95	170.25	147.56	113.52
HLRW	m ³	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07	3.38E-07
ILLRW	m ³	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07	2.91E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	122.33	135.92	115.53	101.94	88.35	67.96	125.48	106.66	94.11	81.56	62.74

Table 19. LCA Results 30 MPa concrete with air & 0.50 w/cm (F-1)

Unit	Baseline 30MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU	30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 25 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 35 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 50 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 15 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 25 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 35 SL	30 MPa concrete with air & 0.50 w/cm (F-1) GU 50 SL		
Environmental impacts												
GWP	kg CO ₂ eq.	292.72	329.02	292.72	268.52	244.32	208.02	307.08	274.07	252.07	230.06	197.05
ODP	kg CFC-11 eq.	7.74E-06	7.57E-06	7.74E-06	7.86E-06	7.97E-06	8.15E-06	7.23E-06	7.45E-06	7.60E-06	7.75E-06	7.98E-06
EP	kg N eq.	0.23	0.25	0.23	0.22	0.21	0.20	0.23	0.22	0.21	0.20	0.19
AP	kg SO ₂ eq.	1.40	1.45	1.40	1.36	1.32	1.26	1.38	1.33	1.30	1.27	1.23
POCP	kg O ₃ eq.	23.58	23.86	23.58	23.39	23.20	22.92	22.85	22.72	22.63	22.55	22.42
Use of primary resources												
RPR _e	MJ, NCV	82.80	91.24	82.80	77.18	71.56	63.13	90.98	82.59	76.99	71.40	63.00
RPR _m	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _e	MJ, NCV	1798.64	1865.83	1798.64	1753.84	1709.04	1641.85	1765.03	1712.95	1678.24	1643.52	1591.45
NRPR _m	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	134.41	158.13	134.41	118.60	102.79	79.07	146.98	124.93	110.23	95.54	73.49
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADP _f	MJ, LHV	602.83	599.10	602.83	605.32	607.81	611.54	593.71	598.25	601.27	604.30	608.84
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.48	2.57	2.48	2.42	2.36	2.27	2.54	2.46	2.40	2.34	2.26
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	243.88	286.91	243.88	215.19	186.51	143.48	271.25	230.57	203.45	176.33	135.65
HLRW	m ³	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07	3.34E-07
ILLRW	m ³	2.87E-07	2.87E-07	2.87E-07	2.87E-07	2.87E-07	2.87E-07	2.87E-07	2.87E-07	2.87E-07	2.87E-07	2.87E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	138.07	162.43	138.07	121.82	105.58	81.22	149.95	127.46	112.46	97.47	74.97

Table 20. LCA Results 32 MPa concrete with air & 0.45 w/cm (C-2)

Unit	Baseline 32MPa concrete with air & 0.45 w/cm (C-2) GU 10 SL	32 MPa concrete with air & 0.45 w/cm (C-2) GU	32 MPa concrete with air & 0.45 w/cm (C-2) GU	32 MPa concrete with air & 0.45 w/cm (C-2) GU	32 MPa concrete with air & 0.45 w/cm (C-2) GU	32 MPa concrete with air & 0.45 w/cm (C-2) GU	32 MPa concrete with air & 0.45 w/cm (C-2) GUL	32 MPa concrete with air & 0.45 w/cm (C-2) GUL	32 MPa concrete with air & 0.45 w/cm (C-2) GUL	32 MPa concrete with air & 0.45 w/cm (C-2) GUL	32 MPa concrete with air & 0.45 w/cm (C-2) GUL	
		15 SL	25 SL	35 SL	50 SL	15 SL	25 SL	35 SL	50 SL			
Environmental impacts												
GWP	kg CO ₂ eq.	326.46	352.57	313.40	287.30	261.19	222.03	328.90	293.29	269.55	245.81	210.20
ODP	kg CFC-11 eq.	8.24E-06	8.12E-06	8.31E-06	8.43E-06	8.56E-06	8.74E-06	7.75E-06	8.00E-06	8.16E-06	8.32E-06	8.56E-06
EP	kg N eq.	0.25	0.27	0.25	0.24	0.23	0.21	0.25	0.23	0.23	0.22	0.20
AP	kg SO ₂ eq.	1.50	1.54	1.48	1.44	1.40	1.34	1.46	1.41	1.38	1.35	1.30
POCP	kg O ₃ eq.	24.91	25.12	24.81	24.61	24.40	24.10	24.03	23.89	23.79	23.70	23.56
Use of primary resources												
RPR _E	MJ, NCV	91.61	97.67	88.57	82.51	76.45	67.35	97.40	88.34	82.31	76.27	67.21
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1921.65	1969.97	1897.48	1849.16	1800.83	1728.34	1861.23	1805.05	1767.60	1730.15	1673.97
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	153.53	170.59	145.00	127.94	110.88	85.30	158.56	134.78	118.92	103.06	79.28
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPF	MJ, LHV	615.53	612.85	616.87	619.56	622.24	626.26	607.03	611.92	615.19	618.45	623.35
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.55	2.61	2.52	2.45	2.39	2.29	2.58	2.49	2.43	2.37	2.28
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	278.57	309.51	263.09	232.15	201.20	154.78	292.62	248.73	219.48	190.22	146.34
HLRW	m ³	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07
ILLRW	m ³	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	157.71	175.23	148.94	131.42	113.90	87.61	161.76	137.50	121.32	105.15	80.88

Table 21. LCA Results 35 MPa concrete with air

Unit	Baseline 35 MPa concrete with air GU 15 SL	35 MPa concrete with air GU	35 MPa concrete with air GU 15 SL	35 MPa concrete with air GU 25 SL	35 MPa concrete with air GU 35 SL	35 MPa concrete with air GU 50 SL	35 MPa concrete with air GUL	35 MPa concrete with air GUL 15 SL	35 MPa concrete with air GUL 25 SL	35 MPa concrete with air GUL 35 SL	35 MPa concrete with air GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	334.49	376.59	334.49	306.42	278.35	236.25	351.15	312.87	287.34	261.82	223.53
ODP	kg CFC-11 eq.	8.89E-06	8.69E-06	8.89E-06	9.02E-06	9.16E-06	9.36E-06	8.30E-06	8.56E-06	8.73E-06	8.90E-06	9.16E-06
EP	kg N eq.	0.26	0.28	0.26	0.25	0.24	0.22	0.27	0.25	0.24	0.23	0.21
AP	kg SO ₂ eq.	1.57	1.63	1.57	1.52	1.48	1.41	1.54	1.49	1.46	1.42	1.37
POCP	kg O ₃ eq.	26.09	26.42	26.09	25.87	25.65	25.33	25.25	25.10	25.00	24.89	24.74
Use of primary resources												
RPR _E	MJ, NCV	93.92	103.70	93.92	87.40	80.88	71.10	103.40	93.67	87.18	80.69	70.95
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1995.18	2073.11	1995.18	1943.23	1891.27	1813.34	1956.21	1895.81	1855.55	1815.28	1754.89
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	155.89	183.40	155.89	137.55	119.21	91.70	170.46	144.89	127.85	110.80	85.23
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPF	MJ, LHV	627.17	622.84	627.17	630.05	632.94	637.27	616.58	621.85	625.36	628.87	634.14
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.56	2.66	2.56	2.49	2.42	2.31	2.63	2.53	2.46	2.40	2.30
Waste and output flows												
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	282.84	332.74	282.84	249.57	216.30	166.40	314.59	267.41	235.95	204.50	157.32
HLRW	m ³	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07	3.33E-07
ILLRW	m ³	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07	2.85E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	160.13	188.38	160.13	141.29	122.45	94.19	173.91	147.82	130.43	113.04	86.95

Table 22. LCA Results 35 MPa concrete with air & 0.40 w/cm (C-1)

Unit	Baseline 35MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) GU 35 SL	35 MPa concrete with air & 0.40 w/cm (C-1) GU 50 SL	35 MPa concrete with air & 0.40 w/cm (C-1) GU 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) GU 35 SL	35 MPa concrete with air & 0.40 w/cm (C-1) GU 50 SL	
	Environmental impacts							
GWP	kg CO ₂ eq.	313.07	313.07	284.38	241.35	293.57	267.48	228.35
ODP	kg CFC-11 eq.	9.21E-06	9.21E-06	9.35E-06	9.55E-06	8.91E-06	9.09E-06	9.35E-06
EP	kg N eq.	0.26	0.26	0.25	0.23	0.25	0.23	0.22
AP	kg SO ₂ eq.	1.55	1.55	1.50	1.44	1.48	1.45	1.39
POCP	kg O ₃ eq.	26.27	26.27	26.05	25.71	25.37	25.27	25.11
Use of primary resources								
RPR _E	MJ, NCV	90.58	90.58	83.92	73.92	90.36	83.73	73.77
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	1986.03	1986.03	1932.93	1853.27	1896.41	1855.26	1793.52
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	140.59	140.59	121.85	93.73	130.68	113.26	87.12
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADPf	MJ, LHV	645.91	645.91	648.86	653.29	641.12	644.70	650.09
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources								
FW	m ³	2.50	2.50	2.43	2.33	2.48	2.41	2.31
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	255.10	255.10	221.09	170.08	241.18	209.03	160.80
HLRW	m ³	3.32E-07	3.32E-07	3.32E-07	3.32E-07	3.32E-07	3.32E-07	3.32E-07
ILLRW	m ³	2.84E-07	2.84E-07	2.84E-07	2.84E-07	2.84E-07	2.84E-07	2.84E-07
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.	144.42	144.42	125.16	96.28	133.32	115.54	88.88

Table 23. LCA Results 40 MPa concrete with air

Unit	Baseline 40 MPa concrete with air GU 15 SL	40 MPa concrete with air GU	40 MPa concrete with air GU 15 SL	40 MPa concrete with air GU 25 SL	40 MPa concrete with air GU 35 SL	40 MPa concrete with air GU 50 SL	40 MPa concrete with air GUL	40 MPa concrete with air GUL 15 SL	40 MPa concrete with air GUL 25 SL	40 MPa concrete with air GUL 35 SL	40 MPa concrete with air GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	361.65	407.45	361.65	331.12	300.59	254.79	379.78	338.13	310.36	282.60	240.95
ODP	kg CFC-11 eq.	9.62E-06	9.40E-06	9.62E-06	9.76E-06	9.91E-06	1.01E-05	8.97E-06	9.25E-06	9.44E-06	9.63E-06	9.92E-06
EP	kg N eq.	0.29	0.31	0.29	0.27	0.26	0.24	0.29	0.27	0.26	0.25	0.23
AP	kg SO ₂ eq.	1.67	1.74	1.67	1.63	1.58	1.51	1.65	1.59	1.55	1.52	1.46
POCP	kg O ₃ eq.	27.62	27.98	27.62	27.38	27.15	26.79	26.71	26.54	26.43	26.32	26.15
Use of primary resources												
RPR _E	MJ, NCV	103.11	113.75	103.11	96.02	88.93	78.29	113.44	102.84	95.78	88.72	78.13
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2133.62	2218.40	2133.62	2077.11	2020.59	1935.81	2091.22	2025.52	1981.72	1937.92	1872.22
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	169.58	199.51	169.58	149.63	129.68	99.75	185.44	157.62	139.08	120.53	92.72
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADPF	MJ, LHV	655.62	650.91	655.62	658.76	661.89	666.60	644.10	649.83	653.65	657.47	663.20
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.60	2.71	2.60	2.52	2.45	2.33	2.67	2.57	2.49	2.42	2.32
Waste and output flows												
HWD	kg	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	307.68	361.97	307.68	271.49	235.30	181.01	342.22	290.89	256.68	222.46	171.14
HLRW	m ³	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07
ILLRW	m ³	2.81E-07	2.81E-07	2.81E-07	2.81E-07	2.81E-07	2.81E-07	2.81E-07	2.81E-07	2.81E-07	2.81E-07	2.81E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	174.19	204.93	174.19	153.70	133.21	102.47	189.18	160.81	141.89	122.97	94.59

Table 24. LCA Results 45MPa concrete with air

Unit	Baseline 45 MPa concrete with air GU 15 SL	45 MPa concrete with air GU	45 MPa concrete with air GU 15 SL	45 MPa concrete with air GU 25 SL	45 MPa concrete with air GU 35 SL	45 MPa concrete with air GU 50 SL	45 MPa concrete with air GUL	45 MPa concrete with air GUL 15 SL	45 MPa concrete with air GUL 25 SL	45 MPa concrete with air GUL 35 SL	45 MPa concrete with air GUL 50 SL	
Environmental impacts												
GWP	kg CO ₂ eq.	379.45	427.75	379.45	347.24	315.04	266.74	398.56	354.64	325.35	296.07	252.15
ODP	kg CFC-11 eq.	1.01E-05	9.88E-06	1.01E-05	1.03E-05	1.04E-05	1.07E-05	9.43E-06	9.73E-06	9.93E-06	1.01E-05	1.04E-05
EP	kg N eq.	0.30	0.32	0.30	0.29	0.27	0.25	0.30	0.28	0.27	0.26	0.24
AP	kg SO ₂ eq.	1.75	1.82	1.75	1.70	1.65	1.57	1.72	1.66	1.62	1.58	1.52
POCP	kg O ₃ eq.	28.76	29.14	28.76	28.51	28.26	27.88	27.80	27.62	27.50	27.39	27.21
Use of primary resources												
RPR _E	MJ, NCV	106.85	118.07	106.85	99.37	91.89	80.67	117.73	106.56	99.12	91.67	80.50
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2211.92	2301.33	2211.92	2152.32	2092.71	2003.31	2167.21	2097.92	2051.73	2005.53	1936.25
NRPR _M	MJ, NCV	0.00	0.00	0.00	0.00	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	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	0.00	0.00	0.00	0.00
NRSF	MJ, NCV	178.84	210.40	178.84	157.80	136.76	105.20	195.57	166.23	146.67	127.12	97.78
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential												
ADP _f	MJ, LHV	659.90	654.94	659.90	663.21	666.52	671.49	647.76	653.80	657.83	661.86	667.90
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources												
FW	m ³	2.64	2.76	2.64	2.56	2.48	2.36	2.72	2.60	2.53	2.45	2.34
Waste and output flows												
HWD	kg	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
NHWD	kg	324.49	381.74	324.49	286.32	248.15	190.90	360.91	306.78	270.69	234.61	180.48
HLRW	m ³	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07	3.30E-07
ILLRW	m ³	2.82E-07	2.82E-07	2.82E-07	2.82E-07	2.82E-07	2.82E-07	2.82E-07	2.82E-07	2.82E-07	2.82E-07	2.82E-07
CRU	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
MER	kg	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00
Additional inventory parameters for transparency												
CCE	kg CO ₂ eq.	183.71	216.12	183.71	162.09	140.48	108.06	199.52	169.59	149.64	129.69	99.76

Table 25. LCA Results 50 MPa concrete with air GUbSF

Unit	Baseline 50 MPa concrete with air GUbSF 20 SL	50 MPa concrete with air GUbSF	50 MPa concrete with air GUbSF 15 SL	50 MPa concrete with air GUbSF 25 SL	50 MPa concrete with air GUbSF 35 SL	50 MPa concrete with air GUbSF 50 SL	
Environmental impacts							
GWP	kg CO ₂ eq.	456.93	535.65	476.61	437.25	397.90	338.86
ODP	kg CFC-11 eq.	1.30E-05	1.23E-05	1.28E-05	1.31E-05	1.34E-05	1.39E-05
EP	kg N eq.	0.37	0.40	0.38	0.36	0.35	0.32
AP	kg SO ₂ eq.	2.19	2.30	2.22	2.17	2.11	2.04
POCP	kg O ₃ eq.	36.71	36.95	36.77	36.65	36.52	36.34
Use of primary resources							
RPR _E	MJ, NCV	130.96	149.05	135.48	126.44	117.39	103.82
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2793.82	2919.92	2825.34	2762.29	2699.24	2604.66
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	209.62	262.03	222.72	196.52	170.32	131.01
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential							
ADPf	MJ, LHV	872.54	861.34	869.74	875.34	880.94	889.35
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources							
FW	m ³	3.36	3.55	3.41	3.31	3.21	3.06
Waste and output flows							
HWD	kg	0.03	0.03	0.03	0.03	0.03	0.03
NHWD	kg	380.34	475.40	404.10	356.57	309.04	237.74
HLRW	m3	4.31E-07	4.31E-07	4.31E-07	4.31E-07	4.31E-07	4.31E-07
ILLRW	m3	3.68E-07	3.68E-07	3.68E-07	3.68E-07	3.68E-07	3.68E-07
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 CO ₂ eq.	215.32	269.15	228.78	201.86	174.95	134.58

Table 26. LCA Results 35 MPa concrete with air & 0.40w/cm(C-1) Self Consolidating Concrete (SCC)

Unit	Baseline 35MPa concrete with air & 0.40 w/cm (C-1) SCC GU 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) SCC GU 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) SCC GU 35 SL	35 MPa concrete with air & 0.40 w/cm (C-1) SCC GU 50 SL	35 MPa concrete with air & 0.40 w/cm (C-1) SCC GUL 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) SCC GUL 35 SL	35 MPa concrete with air & 0.40 w/cm (C-1) SCC GUL 50 SL	
Environmental impacts								
GWP	kg CO ₂ eq.	377.33	377.33	342.46	290.17	353.63	321.92	274.37
ODP	kg CFC-11 eq.	1.11E-05	1.11E-05	1.12E-05	1.15E-05	1.07E-05	1.09E-05	1.12E-05
EP	kg N eq.	0.31	0.31	0.30	0.27	0.30	0.28	0.26
AP	kg SO ₂ eq.	1.82	1.82	1.76	1.68	1.73	1.69	1.63
POCP	kg O ₃ eq.	30.05	30.05	29.78	29.37	28.96	28.83	28.64
Use of primary resources								
RPR _e	MJ, NCV	118.67	118.67	110.58	98.43	118.40	110.34	98.25
RPR _m	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _e	MJ, NCV	2375.96	2375.96	2311.43	2214.63	2267.05	2217.04	2142.03
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	170.85	170.85	148.07	113.90	158.80	137.62	105.87
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	770.53	770.53	774.11	779.48	764.69	769.06	775.60
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources								
FW	m ³	2.62	2.62	2.54	2.41	2.59	2.51	2.38
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	309.98	309.98	268.66	206.67	293.07	254.00	195.40
HLRW	m ³	3.17E-07	3.17E-07	3.17E-07	3.17E-07	3.17E-07	3.17E-07	3.17E-07
ILLRW	m ³	2.70E-07	2.70E-07	2.70E-07	2.70E-07	2.70E-07	2.70E-07	2.70E-07
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.	175.49	175.49	152.09	116.99	162.01	140.41	108.00

Table 27. LCA Results 35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GU/GUL

Unit		Baseline 35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GU 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GU 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GU 35 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GU 50 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUL 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUL 35 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUL 50 SL
Environmental impacts								
GWP	kg CO ₂ eq.	343.50	343.50	311.42	263.30	321.69	292.52	248.76
ODP	kg CFC-11 eq.	1.02E-05	1.02E-05	1.03E-05	1.06E-05	9.85E-06	1.00E-05	1.03E-05
EP	kg N eq.	0.28	0.28	0.27	0.25	0.27	0.26	0.24
AP	kg SO ₂ eq.	1.66	1.66	1.61	1.54	1.59	1.55	1.49
POCP	kg O ₃ eq.	27.74	27.74	27.49	27.11	26.74	26.62	26.45
Use of primary resources								
RPR _E	MJ, NCV	97.71	97.71	90.26	79.08	97.46	90.04	78.92
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2100.35	2100.35	2040.96	1951.89	2000.13	1954.10	1885.07
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	157.22	157.22	136.26	104.82	146.13	126.65	97.42
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential								
ADP _f	MJ, LHV	626.36	626.36	629.66	634.60	620.99	625.00	631.02
ADP _e	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources								
FW	m ³	2.47	2.47	2.39	2.27	2.44	2.36	2.25
Waste and output flows								
HWD	kg	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NHWD	kg	285.27	285.27	247.24	190.20	269.70	233.75	179.82
HLRW	m ³	2.99E-07	2.99E-07	2.99E-07	2.99E-07	2.99E-07	2.99E-07	2.99E-07
ILLRW	m ³	2.53E-07	2.53E-07	2.53E-07	2.53E-07	2.53E-07	2.53E-07	2.53E-07
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.	161.50	161.50	139.96	107.66	149.09	129.21	99.39

Table 28. LCA Results 35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUbSF

Unit		Baseline 35MPa concrete with air & 0.40 w/cm (C-1)Shotcrete GUbSF 10 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUbSF	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUbSF 15 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUbSF 25 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUbSF 35 SL	35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GUbSF 50 SL
Environmental impacts							
GWP	kg CO ₂ eq.	363.99	392.99	349.48	320.48	291.48	247.98
ODP	kg CFC-11 eq.	9.29E-06	9.06E-06	9.41E-06	9.63E-06	9.86E-06	1.02E-05
EP	kg N eq.	0.28	0.29	0.28	0.27	0.25	0.24
AP	kg SO ₂ eq.	1.64	1.68	1.62	1.58	1.54	1.48
POCP	kg O ₃ eq.	26.70	26.79	26.65	26.56	26.47	26.34
Use of primary resources							
RPR _E	MJ, NCV	101.84	108.50	98.50	91.84	85.17	75.18
RPR _M	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
NRPR _E	MJ, NCV	2074.35	2120.81	2051.12	2004.66	1958.20	1888.51
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	173.77	193.07	164.11	144.80	125.50	96.54
RE	MJ, NCV	0.00	0.00	0.00	0.00	0.00	0.00
Abiotic depletion potential							
ADPf	MJ, LHV	614.20	610.07	616.27	620.39	624.52	630.71
ADPe	kg Sb	0.00	0.00	0.00	0.00	0.00	0.00
Consumption of freshwater resources							
FW	m ³	2.52	2.59	2.48	2.41	2.34	2.23
Waste and output flows							
HWD	kg	0.02	0.03	0.02	0.02	0.02	0.02
NHWD	kg	315.27	350.30	297.76	262.74	227.71	175.18
HLRW	m3	2.99E-07	2.99E-07	2.99E-07	2.99E-07	2.99E-07	2.99E-07
ILLRW	m3	2.53E-07	2.53E-07	2.53E-07	2.53E-07	2.53E-07	2.53E-07
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 CO ₂ eq.	178.49	198.32	168.57	148.74	128.91	99.16

References

American Concrete Institute (ACI) 211: Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

American Concrete Institute (ACI) 318: Building Code Requirements for Structural Concrete
ASTM International
ASTM C94: Standard Specification for Ready-Mixed Concrete

Athena Sustainable Materials Institute A Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Manufactured by CRMCA Members – Version 2.0; Prepared by the Athena Sustainable Materials Institute: May 2022

Canadian Standards Association (CSA) A3000: Cementitious materials compendium

Canadian Standards Association (CSA) A23.1/A23.2: Concrete materials and methods of concrete construction/Test methods and standard practices for concrete

Construction Specifications Institute (CSI) MasterFormat Division 03-30-00 Cast-in-Place Concrete

EN 15804:2012 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products

European Federation of Concrete Admixture Associations (2006). EFCA Environmental Declarations for Admixtures. <https://www.efca.info/efca-publications/environmental/>

ISO 21930: 2017 Building construction – Sustainability in building construction – Environmental declaration of building products

ISO 14025: 2006 Environmental labeling and declarations - Type III environmental declarations - Principles and procedures

ISO 14044: 2006 Environmental management - Life cycle assessment - Requirements and guidelines. ISO 14040: 2006 Environmental management - Life cycle assessment - Principles and framework

National Renewable Energy Laboratory 2014. U.S. Life Cycle Inventory Database. <https://www.lcacommons.gov/>.

NSF International (2015) NSF Program Operator Rules

NSF International, Product Category Rule Environmental Product Declarations, PCR for Concrete, V2.1, August 2021. <https://www.nsf.org/standards-development/product-category-rules>