# ASTM International Certified Environmental Product Declaration

<table>
<thead>
<tr>
<th>Declared Product</th>
<th>This Environmental Product Declaration (EPD) covers concrete mixes produced by Concrete Ontario members.</th>
</tr>
</thead>
</table>
| Declaration Owner | Concrete Ontario  
1 Prologis Boulevard, Suite 102B Mississauga, Ontario L5W 0G2 Phone: 905-564-2726  
Website: www.rmcao.org |
| 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  
☐ Internal  
☒ 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:
- 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 Ontario. 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, 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 (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.

<table>
<thead>
<tr>
<th>Building Life Cycle Information Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product stage</strong></td>
</tr>
<tr>
<td>Raw Material supply</td>
</tr>
<tr>
<td>Transport</td>
</tr>
</tbody>
</table>

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).
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 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 Ontario.

<table>
<thead>
<tr>
<th>Materials</th>
<th>LCI Data Source</th>
<th>Geography</th>
<th>Year</th>
<th>Data Quality Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Use Cement</td>
<td>Weighted Average of Results Specific to Concrete Producers in Region</td>
<td>Canada</td>
<td>2020-2021</td>
<td>• Technology: very good</td>
</tr>
<tr>
<td>ASTM C150, C595, C1157 CSA A3000</td>
<td></td>
<td></td>
<td></td>
<td>• Time: very good</td>
</tr>
<tr>
<td>General Use Limestone Cement</td>
<td>Weighted Average of Results Specific to Concrete Producers in Region</td>
<td>Canada</td>
<td>2020-2021</td>
<td>• Completeness: very good</td>
</tr>
<tr>
<td>ASTM C150, C595, C1157 CSA A3000</td>
<td></td>
<td></td>
<td></td>
<td>• Reliability: very good</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>None, no incoming burden, only inbound transport was considered</td>
<td>N/A</td>
<td>N/A</td>
<td>• Technology: good</td>
</tr>
<tr>
<td>ASTM C618 CSA A3000</td>
<td></td>
<td></td>
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<td>• Time: good</td>
</tr>
<tr>
<td>Slag Cement</td>
<td>Slag Cement Association N. America EPD Slag Cement, 2021</td>
<td>N. America</td>
<td>2021</td>
<td>• Completeness: very good</td>
</tr>
<tr>
<td>ASTM C989 CSA A3000</td>
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<td>• Reliability: very good</td>
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<tr>
<td>Crushed Aggregates coarse and fine</td>
<td>ecoinvent 3.4: Gravel, crushed (RoW) production Cut-off, U Modified with regional electricity</td>
<td>EU/Canada</td>
<td>2004</td>
<td>• Technology: good</td>
</tr>
<tr>
<td>ASTM C33 CSA A23.1/A23.2</td>
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<td></td>
<td>• Time: fair</td>
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<tr>
<td>Natural Aggregates coarse and fine</td>
<td>ecoinvent 3.4: Gravel, round (RoW) gravel and sand quarry operation Cut-off, U Modified with regional electricity</td>
<td>EU/Canada</td>
<td>2004</td>
<td>• Data is twelve years old but technology remains consistent across the industry</td>
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<tr>
<td>ASTM C30 CSA A23.1/A23.2</td>
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<td>• Geography: good</td>
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<td>Admixtures</td>
<td>EFCA EPDs for Air Entrainers, Plasticizers and superplasticizers (2015)</td>
<td>EU</td>
<td>2015</td>
<td>• Completeness: very good</td>
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<tr>
<td>ASTM C 494, ASTM C260</td>
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<td>• Reliability: very good</td>
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<tr>
<td>Water</td>
<td>ecoinvent 3.4: Tap water (RoW) market for Cut-off, U</td>
<td>Global</td>
<td>2011</td>
<td>• Technology: very good</td>
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<td>ASTM C1602 CSA A23.1/A23.2</td>
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<td>• Completeness: good</td>
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<td>• Reliability: good</td>
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Table 1. A1 - Raw Material Supply
Table 2. A2 - Transportation

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<tr>
<th>Process</th>
<th>LCI Data Source</th>
<th>Geography</th>
<th>Year</th>
<th>Data Quality Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Transportation</td>
<td>USLCI 2014: Transport, combination truck, short-haul, diesel powered/tkm/RNA</td>
<td>USA</td>
<td>2007</td>
<td>- Technology: good</td>
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<td>- Time: fair</td>
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<td>- Geography: very good</td>
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<td>- Completeness: good</td>
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<td>- Reliability: good</td>
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<tr>
<td>Rail Transportation</td>
<td>USLCI 2014: Transport, train, diesel powered / US U</td>
<td>USA</td>
<td>2007</td>
<td>- Technology: good</td>
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<td>- Time: fair</td>
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<td>- Geography: very good</td>
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<td>- Completeness: good</td>
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<td>- Reliability: good</td>
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<tr>
<td>Ocean Transportation</td>
<td>USLCI 2014: Transport, ocean freighter, average fuel mix / US U</td>
<td>USA</td>
<td>2007</td>
<td>- Technology: good</td>
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<td>- Reliability: good</td>
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Table 3. A3 - Manufacturing

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<tr>
<th>Process</th>
<th>LCI Data Source</th>
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<th>Year</th>
<th>Data Quality Assessment</th>
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</thead>
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<tr>
<td>Electricity</td>
<td>Electricity, low voltage, at grid, (CA)</td>
<td>Regional</td>
<td>2015</td>
<td>- Technology: very good</td>
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<td>- Time: good</td>
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<td>- Geography: very good</td>
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<td>- Reliability: good</td>
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<tr>
<td>Natural Gas</td>
<td>USLCI 2014: Natural gas, combusted in industrial boiler / US</td>
<td>US</td>
<td>2008</td>
<td>- Technology: very good</td>
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<td>- Reliability: good</td>
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<tr>
<td>Hazardous Waste</td>
<td>ecoinvent 3.4: Hazardous waste, for incineration (ROW) treatment of hazardous waste, hazardous waste incineration Alloc Rec, U</td>
<td>EU</td>
<td>2008</td>
<td>- Technology: good</td>
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<td>- Reliability: very good</td>
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<tr>
<td>Non-Hazardous Waste</td>
<td>ecoinvent 3.4: Inert waste (RoW)</td>
<td>treatment of, sanitary landfill Alloc Rec, U</td>
<td>EU</td>
<td>2008</td>
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<td>- Reliability: very good</td>
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</tbody>
</table>

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 27 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.

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>
<thead>
<tr>
<th>Table 4. Life Cycle Category Indicators and Inventory Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Core Mandatory Impact Indicator</strong></td>
</tr>
<tr>
<td>Abbreviation</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Global warming potential</td>
</tr>
<tr>
<td>Depletion potential of the stratospheric ozone layer</td>
</tr>
<tr>
<td>Acidification potential of soil and water sources</td>
</tr>
<tr>
<td>Eutrophication potential</td>
</tr>
<tr>
<td>Photochemical smog creation potential</td>
</tr>
</tbody>
</table>

**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; Calcination and carbonation emissions | FW  | m3 | LCI Indicator |
| Hazardous waste disposed* | HWD  | kg | LCI Indicator |
| Non-hazardous waste disposed* | NHWD  | kg | LCI Indicator |
| High-level radioactive waste* | HLRW | m3 | LCI Indicator |
| Intermediate- and low-level radioactive waste* | ILLRW | m3 | 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 |
Table 5. LCA Results 20 MPa concrete without air

<table>
<thead>
<tr>
<th>Environmental impacts</th>
<th>Baseline 20MPa concrete without air GU 10 SL</th>
<th>20 MPa concrete without air GU 15 SL</th>
<th>20 MPa concrete without air GU 25 SL</th>
<th>20 MPa concrete without air GU 35 SL</th>
<th>20 MPa concrete without air GU 50 SL</th>
<th>20 MPa concrete without air GUL 15 SL</th>
<th>20 MPa concrete without air GUL 25 SL</th>
<th>20 MPa concrete without air GUL 35 SL</th>
<th>20 MPa concrete without air GUL 50 SL</th>
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</thead>
<tbody>
<tr>
<td>GWP kg CO₂ eq.</td>
<td>220.29</td>
<td>236.90</td>
<td>211.99</td>
<td>195.38</td>
<td>178.77</td>
<td>153.85</td>
<td>221.84</td>
<td>199.19</td>
<td>184.08</td>
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<tr>
<td>ODP kg CFC-11 eq.</td>
<td>5.46E-06</td>
<td>5.38E-06</td>
<td>5.50E-06</td>
<td>5.58E-06</td>
<td>5.66E-06</td>
<td>5.78E-06</td>
<td>5.15E-06</td>
<td>5.31E-06</td>
<td>5.41E-06</td>
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<td>EP kg N₂eq.</td>
<td>0.17</td>
<td>0.18</td>
<td>0.17</td>
<td>0.16</td>
<td>0.15</td>
<td>0.14</td>
<td>0.17</td>
<td>0.16</td>
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<td>AP kg SO₂ eq.</td>
<td>1.09</td>
<td>1.12</td>
<td>1.08</td>
<td>1.05</td>
<td>1.02</td>
<td>0.99</td>
<td>1.06</td>
<td>1.03</td>
<td>1.01</td>
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<td>POCP kg O₃ eq.</td>
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<td>19.12</td>
<td>18.93</td>
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<td>18.67</td>
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Table 7. LCA Results 25 MPa concrete without air & 0.55 w/cm (N-CF)

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<td>245.55</td>
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<td>144.46</td>
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<td>MR kg</td>
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<td>0.00</td>
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Table 10. LCA Results 40 MPa concrete without air

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<th>40MPa concrete without air GU 35 SL</th>
<th>40MPa concrete without air GU 50 SL</th>
<th>40MPa concrete without air GUL</th>
<th>40MPa concrete without air GUL 15 SL</th>
<th>40MPa concrete without air GUL 25 SL</th>
<th>40MPa concrete without air GUL 35 SL</th>
<th>40MPa concrete without air GUL 50 SL</th>
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<td>GWP</td>
<td>kg CO₂ eq.</td>
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<td>299.07</td>
<td>271.89</td>
<td>231.13</td>
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<td>305.31</td>
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<td>kg CFC-11 eq.</td>
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<td>8.44E-06</td>
<td>8.64E-06</td>
<td>8.77E-06</td>
<td>9.09E-06</td>
<td>9.06E-06</td>
<td>8.32E-06</td>
<td>8.48E-06</td>
<td>8.65E-06</td>
<td>8.90E-06</td>
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<td>EP</td>
<td>kg N eq.</td>
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<td>0.28</td>
<td>0.26</td>
<td>0.25</td>
<td>0.23</td>
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<td>0.23</td>
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<td>AP</td>
<td>kg SO₂ eq.</td>
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<td>1.54</td>
<td>1.50</td>
<td>1.45</td>
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<td>POCP</td>
<td>kg O₃ eq.</td>
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<td>25.74</td>
<td>25.53</td>
<td>25.32</td>
<td>25.00</td>
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<td>24.78</td>
<td>24.68</td>
<td>24.59</td>
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</table>

Use of primary resources

| RPRₕ | MJ, NCV | 93.10 | 102.57 | 93.10 | 86.79 | 80.48 | 71.01 | 102.29 | 92.86 | 86.58 | 80.29 | 70.87 |
| RPRₗ | MJ, NCV | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| NRPRₕ | MJ, NCV | 1975.27 | 2050.74 | 1975.27 | 1924.97 | 1874.66 | 1799.19 | 1937.53 | 1879.05 | 1840.06 | 1801.07 | 1742.59 |
| NRPRₗ | 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

| ADPF | MJ, LHV | 644.57 | 640.38 | 644.57 | 647.36 | 650.16 | 654.35 | 634.32 | 639.42 | 642.82 | 646.22 | 651.32 |
| 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 | m³ | 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 |
| ILRW | m³ | 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 CO₂ eq. | 155.06 | 182.42 | 155.06 | 136.82 | 118.57 | 91.21 | 168.40 | 143.14 | 126.30 | 109.46 | 84.20 |
Table 11. LCA Results 45 MPa concrete without air

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<th>Environmental impacts</th>
<th>Baseline 45 MPa concrete without air</th>
<th>45 MPa concrete without air</th>
<th>45 MPa concrete without air</th>
<th>45 MPa concrete without air</th>
<th>45 MPa concrete without air</th>
<th>45 MPa concrete without air</th>
<th>45 MPa concrete without air</th>
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<td>GU 15 SL</td>
<td>GU 25 SL</td>
<td>GU 35 SL</td>
<td>GU 50 SL</td>
<td>GUL</td>
<td>GUL</td>
<td>GUL</td>
<td>GUL</td>
<td>GUL</td>
<td>GUL</td>
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<td>GWP (kg CO₂ eq.)</td>
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<td>290.99</td>
<td>246.83</td>
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<td>300.42</td>
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<td>0.28</td>
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<td>1.47</td>
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<td>RPRₚ (MJ, NCV)</td>
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<td>2.89E-07</td>
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<td>EE (kg)</td>
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<td>Additional inventory parameters for transparency</td>
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</tr>
<tr>
<td>CCE (kg CO₂ eq.)</td>
<td>167.98</td>
<td>197.62</td>
<td>167.98</td>
<td>148.22</td>
<td>128.46</td>
<td>98.81</td>
<td>182.44</td>
<td>155.07</td>
<td>136.83</td>
<td>118.58</td>
<td>91.22</td>
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Table 12. LCA Results 50 MPa concrete without air GUbSF

<table>
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<th>Environmental impacts</th>
<th>Unit</th>
<th>Baseline 50 MPa concrete without air GUbSF 20SL</th>
<th>50 MPa concrete without air GUbSF</th>
<th>50 MPa concrete without air GUbSF 15 SL</th>
<th>50 MPa concrete without air GUbSF 25 SL</th>
<th>50 MPa concrete without air GUbSF 35 SL</th>
<th>50 MPa concrete without air GUbSF 50 SL</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWP</td>
<td>kg CO₂ eq.</td>
<td>335.76</td>
<td>393.19</td>
<td>350.12</td>
<td>321.41</td>
<td>292.69</td>
<td>249.62</td>
</tr>
<tr>
<td>ODP</td>
<td>kg CFC-11 eq.</td>
<td>9.50E-06</td>
<td>9.04E-06</td>
<td>9.38E-06</td>
<td>9.61E-06</td>
<td>9.83E-06</td>
<td>1.02E-05</td>
</tr>
<tr>
<td>EP</td>
<td>kg Neq.</td>
<td>0.27</td>
<td>0.30</td>
<td>0.28</td>
<td>0.27</td>
<td>0.26</td>
<td>0.24</td>
</tr>
<tr>
<td>AP</td>
<td>kg SO₂ eq.</td>
<td>1.63</td>
<td>1.70</td>
<td>1.65</td>
<td>1.61</td>
<td>1.57</td>
<td>1.51</td>
</tr>
<tr>
<td>POCP</td>
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Table 14. LCA Results 60 MPa concrete without air GUbSF

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### Table 15. LCA Results 70MPa concrete without air GUbSF

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Table 16. LCA Results 20 MPa concrete with air & 0.70 w/cm

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## Table 17. LCA Results 25 MPa concrete with air & 0.55 w/cm (F-2)

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Table 19. LCA Results 32 MPa concrete with air & 0.45 w/cm (C-2)

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**Table 20. LCA Results 35 MPa concrete with air**

**Environmental impacts**

- **GWP**: kg CO₂ eq.
- **ODP**: kg CFC-11 eq.
- **EP**: kg N eq.
- **AP**: kg SO₂ eq.
- **POCP**: kg O₃ eq.

**Use of primary resources**

- **RPR**: MJ, NCV
- **RPRₚ**: MJ, NCV
- **NRPR**: MJ, NCV
- **NRPRₚ**: MJ, NCV

**Use of secondary resources**

- **SM**: kg
- **RSF**: MJ, NCV
- **NRSF**: MJ, NCV
- **RE**: MJ, NCV

**Abiotic depletion potential**

- **ADPf**: MJ, LHV
- **ADPe**: kg Sb

**Consumption of freshwater resources**

- **FW**: m³

**Waste and outputs**

- **HWD**: kg
- **NHWD**: kg
- **HLRW**: m³
- **LLRW**: m³
- **CRU**: kg
- **MR**: kg
- **MER**: kg
- **EE**: kg

**Additional inventory parameters for transparency**

- **CCE**: kg CO₂ eq.
Table 21. LCA Results 35 MPa concrete with air & 0.40 w/cm (C-1)

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<th>Baseline 35MPa concrete with air &amp; 0.40 w/cm (C-1) GU 25 SL</th>
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## Table 22. LCA Results 40 MPa concrete with air

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Table 23. LCA Results 45 MPa concrete with air

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<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td></td>
<td>MR kg</td>
<td>0.00</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td></td>
<td>MER kg</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td></td>
<td>EE kg</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
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<td>CCE kg CO₂ eq.</td>
<td>183.71</td>
<td>216.12</td>
<td>183.71</td>
<td>162.09</td>
<td>140.48</td>
<td>108.06</td>
<td>199.52</td>
<td>169.59</td>
<td>149.64</td>
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### Table 24. LCA Results 50 MPa concrete with air GUbSF

<table>
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<tr>
<th>Environmental impacts</th>
<th>Unit</th>
<th>Baseline 50 MPa concrete with air GUbSF 20 SL</th>
<th>50 MPa concrete with air GUbSF 25 SL</th>
<th>50 MPa concrete with air GUbSF 35 SL</th>
<th>50 MPa concrete with air GUbSF 50 SL</th>
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</thead>
<tbody>
<tr>
<td>GWP</td>
<td>kg CO₂ eq.</td>
<td>456.93</td>
<td>535.65</td>
<td>476.61</td>
<td>437.25</td>
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<tr>
<td>ODP</td>
<td>kg CFC-11 eq.</td>
<td>1.30E-05</td>
<td>1.23E-05</td>
<td>1.28E-05</td>
<td>1.31E-05</td>
</tr>
<tr>
<td>EP</td>
<td>kg N eq.</td>
<td>0.37</td>
<td>0.40</td>
<td>0.38</td>
<td>0.36</td>
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<tr>
<td>AP</td>
<td>kg SO₂ eq.</td>
<td>2.19</td>
<td>2.30</td>
<td>2.22</td>
<td>2.17</td>
</tr>
<tr>
<td>POCP</td>
<td>kg O₃ eq.</td>
<td>36.71</td>
<td>36.95</td>
<td>36.77</td>
<td>36.65</td>
</tr>
</tbody>
</table>

### Use of primary resources

| RPR₆ | MJ, NCV | 130.96 | 149.05 | 135.48 | 126.44 | 117.39 | 103.82 |
| RPR₉ | MJ, NCV | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| NRPR₆ | MJ, NCV | 2793.82 | 2919.92 | 2825.34 | 2762.29 | 2699.24 | 2604.66 |
| NRPR₉ | 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 | m³ | 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 |
| LLRW | 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 CO₂ eq. | 215.32 | 269.15 | 228.78 | 201.86 | 174.95 | 134.58 |
Table 25. LCA Results 35 MPa concrete with air & 0.40 w/cm (C-1) Self Consolidating Concrete (SCC)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Baseline 35 MPa concrete with air &amp; 0.40 w/cm (C-1) SCC GU 25 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) SCC GU 35 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) SCC GU 50 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) SCC GU 25 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) SCC GU 35 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) SCC GU 50 SL</th>
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<tr>
<td></td>
<td>Environmental impacts</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>GWP kg CO₂ eq.</td>
<td>377.33</td>
<td>377.33</td>
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<td>353.63</td>
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<td>ODP kg CFC-11 eq.</td>
<td>1.11E-05</td>
<td>1.11E-05</td>
<td>1.12E-05</td>
<td>1.15E-05</td>
<td>1.07E-05</td>
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<tr>
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<td>EP kg N eq.</td>
<td>0.31</td>
<td>0.31</td>
<td>0.30</td>
<td>0.27</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>AP kg SO₂ eq.</td>
<td>1.82</td>
<td>1.82</td>
<td>1.76</td>
<td>1.68</td>
<td>1.73</td>
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<td>POCP kg O₃ eq.</td>
<td>30.05</td>
<td>30.05</td>
<td>29.78</td>
<td>29.37</td>
<td>28.96</td>
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</tr>
<tr>
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<td>RPRₑ MJ, NCV</td>
<td>118.67</td>
<td>118.67</td>
<td>110.58</td>
<td>98.43</td>
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<td>2375.96</td>
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<td>Use of secondary resources</td>
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<td>0.00</td>
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<tr>
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<td>RSF MJ, NCV</td>
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<td>0.00</td>
<td>0.00</td>
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<td>170.85</td>
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<td>ADPF MJ, LHV</td>
<td>770.53</td>
<td>770.53</td>
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<tr>
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<td>FW m³</td>
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<td>0.02</td>
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<td>ILRW m³</td>
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<tr>
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<tr>
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<td>MER kg</td>
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<tr>
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<td>EE kg</td>
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<td>Additional inventory parameters for transparency</td>
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<tr>
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<td>CCE kg CO₂ eq.</td>
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<td>175.49</td>
<td>152.09</td>
<td>116.99</td>
<td>162.01</td>
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Table 26. LCA Results 35 MPa concrete with air & 0.40 w/cm (C-1) Shotcrete GU/GUL

<table>
<thead>
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<th>Unit</th>
<th>Baseline 35MPa concrete with air &amp; 0.40 w/cm (C-1) Shotcrete GU 25 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) Shotcrete GU 25 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) Shotcrete GU 35 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) Shotcrete GU 50 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) Shotcrete GUL 25 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) Shotcrete GUL 35 SL</th>
<th>35 MPa concrete with air &amp; 0.40 w/cm (C-1) Shotcrete GUL 50 SL</th>
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<td>Environmental impacts</td>
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<td>GWP kg CO₂ eq.</td>
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<td>343.50</td>
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<td>1.02E-05</td>
<td>1.03E-05</td>
<td>1.06E-05</td>
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<td>1.59</td>
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<tr>
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<td>27.74</td>
<td>27.49</td>
<td>27.11</td>
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<td>26.45</td>
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<tr>
<td>RPRₑ MJ, NCV</td>
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<td>97.71</td>
<td>90.26</td>
<td>79.08</td>
<td>97.46</td>
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<td>RSF MJ, NCV</td>
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<td>0.00</td>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>NRSF MJ, NCV</td>
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<td>157.22</td>
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<td>104.82</td>
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<td>126.65</td>
<td>97.42</td>
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<td>634.60</td>
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<td>247.24</td>
<td>190.20</td>
<td>269.70</td>
<td>233.75</td>
<td>179.82</td>
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<td>2.53E-07</td>
<td>2.53E-07</td>
<td>2.53E-07</td>
<td>2.53E-07</td>
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</tr>
<tr>
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<td>0.00</td>
<td>0.00</td>
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<tr>
<td>MR kg</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>MER kg</td>
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<td>0.00</td>
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<td>Additional inventory parameters for transparency</td>
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<tr>
<td>CCE kg CO₂ eq.</td>
<td>161.50</td>
<td>161.50</td>
<td>139.96</td>
<td>107.66</td>
<td>149.09</td>
<td>129.21</td>
<td>99.39</td>
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<td>Table 27. LCA Results 35 MPa concrete with air &amp; 0.40 w/cm (C-1) Shotcrete GUbSF</td>
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