LIFE CYCLE ASSESSMENT (LCA) ANALYSIS TOWARDS A SUSTAINABLE CEMENT INDUSTRY FOR SRI LANKA : AN ANALYSIS OF THREE PROCESS PATHWAYS

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“Consumers are increasingly interested in the world behind the product they buy. Life cycle thinking implies that everyone in the whole chain of a product’s life cycle, from cradle to grave, has a responsibility and a role to play, taking into account all the relevant external effects. The impacts of all life cycle stages need to be considered comprehensively when taking informed decisions on production and consumption patterns, policies and management strategies.”

Klaus Toepfer, Former Executive Director, UNEP
Declaration of the candidate & supervisor

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Signature of the Supervisor (Prof Ajith de Alwis)    Date
Abstract

Cement has already become an essential commodity which contributes for global development which also contributes globally ~5% of man-made CO₂ as an adverse environmental impact, during its production phase. Cement manufacturers have already implemented programs aiming to reduce their GHG footprint introducing clinker substituted cement types, utilizing alternative fuels and optimizing the cement manufacturing process. LCA is a tool which can be used to quantify & assess the environmental impacts for a selected scope. Study covers a detail LCA study on different cement manufacturing scenarios selecting GHG emission as the main impact category for a local integrated cement manufacturing facility.

As the scope of the LCA ‘cradle to gate’ approach was selected and functional unit defined as ‘one tonne of cementitious material’ in order to compare with different clinker percentage cement types. Holcim (Lanka) Ltd – Puttalam Cement Works was selected for the study as the only operating integrated cement manufacturing facility in Sri Lanka. For the scope inland transportation GHG contributions were also included as an extended scope item.

An author designed simple LCA tool ‘Cement LCA Calculator’ was introduced and used to life cycle inventorying and analyzing process. This tool is compatible with the cement CO₂ protocol published by the WBCSD (World Business Council for Sustainable Development) aligned with GRI (Global Reporting Initiative) & International Panel for Climate Change (IPCC) guidelines.

LCA analysis was categorized into two process units. More than 90% of GHG generated inside the facility due to calcination and kiln fuel combustion in the baseline scenario where no alternative fuels being used. In year 2007 the thermal substitution rate was 19.9% and average overall clinker factor was 76.5%. Also it has been shown the reduction from 913 to 764 net kgCO₂e/tonne of cementitious material from the baseline year – 2001 to 2007. Reported neutral absolute CO₂ volumes were 39,940 tonnes in year 2007. However a small increase shown in the local transporting area from 0.56 to 1.31 net kgCO₂e/tonne of cementitious material due to increasing alternative fuel transporting activities. The net savings of CO₂ by utilizing waste derived fuels were 3,464 tCO₂e in year 2007 as per the ‘Cement LCA Calculator’. Research outcomes also opened a number of LCA based research options as future research areas.

The LCA study has clearly shown the GHG benefits a reduction of 16% by using alternative fuels and clinker substituted products. Both these corporate initiatives are way forward actions towards sustainable cement manufacturing process, which Holcim (Lanka) Ltd is committed by its group strategies. Introduced Cement LCA Calculator can also be used on finding CO₂ minimizing strategies in future cement industry focused ecological improvement studies.
Dedication

To my dearest father
Acknowledgement

I am heartily thankful to my supervisor, Prof Ajith de Alwis, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject. Further I wish to extend my gratitude to Head and the all the academic staff of Department of Chemical & Process Engineering of University of Moratuwa for the given academic support. Special gratitude goes to Dr Manisha Gunasekara for the given guidance and critical commenting during the reviews. Also acknowledge the support given by Post Graduate Institute staff for supporting me to ease the administrative work. During the research period the support given by PG coordinators Irosha Kularatne, Dinuka Prasanga and Chamila Wickramasinghe are highly appreciated.

I highly extend my gratitude to my work place Holcim (Lanka) Ltd for the given extensive support to initiate this research and carry out it with required resources. Support given by my former supervisors Mr George Nicole, Mr Rathika de Silva are highly appreciated on this regard.

Life Cycle Assessment is still not a popular subject in Sri Lankan context. In order to overcome the faced technical and theoretical constraints given cross boundary support by Dr Rudiger Stenger (Head of Environment) and Dominique Bouchi from Holcim Group Support, Switzerland, Dr. Fredy Dinkel (Carbotech AG in Zurich), Dr. Ir. Joost G. Vogtländer (Associate Professor at the Delft University of Technology) and Dr Rita Schenck (American Center for Life Cycle Assessment - ACLCA) are also highly appreciated.

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Last but not least the support and motivation given by my beloved wife Achala Fernando is highly appreciated. Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the project.
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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>%w/w</td>
<td>Percentage by weight</td>
</tr>
<tr>
<td>°C</td>
<td>Degrees Celsius</td>
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<tr>
<td>ABC</td>
<td>Application based cement</td>
</tr>
<tr>
<td>AF</td>
<td>Alternative fuels</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>Aluminum oxide</td>
</tr>
<tr>
<td>BDP</td>
<td>Best demonstrated performance</td>
</tr>
<tr>
<td>BSEN</td>
<td>British Standard European Norm</td>
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<tr>
<td>BSI</td>
<td>British Standard Institute</td>
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<tr>
<td>CaO</td>
<td>Calcium oxide</td>
</tr>
<tr>
<td>cem</td>
<td>Cementitious material</td>
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<tr>
<td>CEMs</td>
<td>Continuous emission monitoring systems</td>
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<tr>
<td>CER</td>
<td>Certified emission reductions</td>
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<tr>
<td>CKD</td>
<td>Cement kiln dust</td>
</tr>
<tr>
<td>cli</td>
<td>Clinker</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>COD</td>
<td>Chemical Oxygen demand</td>
</tr>
<tr>
<td>CSI</td>
<td>Cement sustainability initiative</td>
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<tr>
<td>EH&amp;S</td>
<td>Environmental, health and safety</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental impact assessment</td>
</tr>
<tr>
<td>EP</td>
<td>Electrostatic precipitators</td>
</tr>
<tr>
<td>EPL</td>
<td>Environmental protection license</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise resource planning</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>Ferric oxide</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross domestic product</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse gas</td>
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<tr>
<td>GRI</td>
<td>Global reporting initiative</td>
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<td>Gt</td>
<td>Gigatonnes</td>
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<td>HCl</td>
<td>Hydrogen chloride</td>
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<tr>
<td>PM</td>
<td>Particulate matter (dust)</td>
</tr>
<tr>
<td>ppm</td>
<td>Parts per million</td>
</tr>
<tr>
<td>s</td>
<td>Seconds</td>
</tr>
<tr>
<td>SETAC</td>
<td>Society for Environmental Toxicology and Chemistry</td>
</tr>
<tr>
<td>SF₆</td>
<td>Sulfur hexafluoride</td>
</tr>
<tr>
<td>SiO₂</td>
<td>Silicon dioxide</td>
</tr>
<tr>
<td>SLSI</td>
<td>Sri Lanka Standards Institute</td>
</tr>
<tr>
<td>SO₂</td>
<td>Sulfur dioxide</td>
</tr>
<tr>
<td>t,ton</td>
<td>Metric ton</td>
</tr>
<tr>
<td>tCO₂e</td>
<td>Metric ton of carbon dioxide equivalent</td>
</tr>
<tr>
<td>TEQ</td>
<td>Toxic equivalent quotient</td>
</tr>
<tr>
<td>TiO₂</td>
<td>Titanium oxide</td>
</tr>
<tr>
<td>TSP</td>
<td>Total suspended particles</td>
</tr>
<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
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<tr>
<td>VOC</td>
<td>Volatile organic compounds</td>
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<tr>
<td>WBCSD</td>
<td>World Business Council for Sustainable Development</td>
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<tr>
<td>WRI</td>
<td>World Resource Initiative</td>
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<td>wrt</td>
<td>with respect to</td>
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