Recycling of cement

Existing research and opportunities in Thailand

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Introduction

The underlying report is a research on the possibility of recycling cement in Thailand. By desk research of already existing research and commercial applications in other parts of the world.

Waste cement can be reused through various techniques, including recycling concrete rubble and reusing cement in new concrete mixes. This process is often called "concrete recycling."

The annual cement production in Thailand roughly produces 60 Mio tons of which YY Mio tons is so-called slack cement and will be used for landfill. In addition reconstruction works are generating additional slack cement of around ZZ Mio tons on an annual base.

Existing concrete recycling technologies

1. Recycling of Concrete Rubble: Concrete rubble can be recycled by crushing it into smaller pieces, which can then be used as aggregate in new concrete mixes. This not only reduces waste but also decreases the need for new raw materials.

2. Use of Recycled Cement: The cement in old concrete can be recovered and reused. This process is known as "cement recovery" and can be carried out using thermal or chemical methods to separate the cement from the rest of the concrete.

See more details in Appendix 1

3. Carbon Uptake by Recycled Concrete: Part of the research focuses on the ability of recycled concrete to absorb CO_2. This process, known as "carbonation," can help reduce the environmental impact of concrete production by capturing CO_2 from the atmosphere.

See more details in Appendix 2.

Sustainability of recycling cement

Reusing waste cement can lead to significant energy and environmental savings. Recovering cement from waste concrete requires less energy than producing new cement from raw materials, and it also prevents emissions associated with limestone extraction and processing, a key ingredient in cement.

Reusing waste cement aligns well with the principles of the circular economy, which focus on reducing waste, reusing materials, and maximizing the lifespan of resources.

Non-structural usage

Research institutions and universities worldwide have published various studies on the feasibility and benefits of reusing waste cement, including techniques for improving the quality of recycled concrete and its use in different applications such as road construction, foundations, and other non-structural uses.

Status of recycling cement in SEA & Thailand specifically

In Southeast Asia, several countries and companies are actively involved in recycling cement and using sustainable building materials.

Recycled Aggregate Concrete (RAC) in Southeast Asia

According to research, the use of recycled aggregate concrete is being explored across the region, although the uptake is relatively slow due to the lack of economic sustainability and knowledge. Studies are focused on developing sustainable, durable, and cost-effective "green concrete" using recycled aggregates, which could play a significant role in future construction practices across the region. A review of studies on recycled aggregate concrete in Southeast Asia indicates that although there is research and pilot projects, practical implementation is still limited. The key challenges are the lack of economic viability and awareness of the potential benefits of using recycled materials

Cambodia

The main cement plant in Cambodia is Kampot Cement, which is largely owned by Siam Cement Group. Cambodia's cement industry relies on imports to meet domestic demand, and while there is local production, significant recycling initiatives are not mentioned as a primary activity in Cambodia’s cement industry.

There is little information regarding quantities of cement recycling, as the country relies significantly on imports to meet cement demand.

Indonesia

The cement industry in Indonesia is large, with companies like Semen Indonesia, Indocement, and Holcim being key players. There are efforts to use alternative fuels, such as biomass, to lower the carbon footprint of cement production. Semen Indonesia has also been recognized for its initiatives in using biomass as a sustainable fuel source, contributing to the circular economy by replacing part of traditional fuel use.

While the country has significant cement production capabilities, the focus has been more on alternative fuel usage (such as biomass) rather than recycling cement itself. Semen Indonesia and other companies have begun implementing measures to utilize more sustainable resources, but no specific figures for recycled cement are mentioned.

Singapore

EP Power Minerals Asia Pte. Ltd., based in Singapore, is collaborating with local partners to develop activities involving cementitious materials like fly ash, granulated blast furnace slag, and bottom ash. This helps reduce the need for virgin raw materials in cement production.

Companies like EP Power Minerals Asia are actively involved in recycling by-products such as fly ash and slag. However, specific volumes of cement recycled have not been disclosed.

Vietnam

In Vietnam, Hoang Son Fly Ash and Cement JSC is also active in utilizing by-products from thermal power plants in cement production, promoting the recycling of industrial by-products in the process.

Companies like Hoang Son Fly Ash and Cement JSC are actively involved in recycling by-products such as fly ash and slag. However, specific volumes of cement recycled have not been disclosed.

Thailand

In Thailand there are few companies actively involved in cement recycling and related waste management initiatives. These companies are leading efforts to integrate recycling into cement production, reduce carbon footprints, and align their operations with circular economy principles in Thailand and the broader Southeast Asian region

Siam City Cement (SCCC) and Siam Cement Group (SCG) are both involved in recycling and reusing waste materials in their cement production processes as part of their sustainability efforts.

INSEE Ecocycle (part of Siam City Cement Group) offers comprehensive waste management services, including recycling and the use of refuse-derived fuel (RDF) for powering cement kilns. They aim for a "Zero Waste to Landfill" approach and manage various types of waste streams, including industrial and municipal solid waste, which helps reduce environmental impact. They also have operations in Vietnam, Cambodia, and Sri Lanka focused on sustainable waste processing and recycling initiatives.

Siam City Cement aims to increase its use of waste-derived fuels and raw materials, specifically by doubling the use of such materials in clinker production to over 1.0 million tons per year. They are also targeting an increased use of by-products like fly ash, slag, and gypsum, with plans to use over 1.7 million tons of these materials annually in cement production. Their "Ecocycle" business also focuses on waste management and recycling, helping to keep industrial and hazardous waste out of landfills and contributing to the circular economy by using these waste materials as fuel for cement kilns and in cementitious products

Siam Cement Group (SCG) is the largest and oldest cement and building materials company in Thailand and Southeast Asia. They have been expanding their operations towards recycling and sustainability, focusing on using recycled aggregates and other recycled materials in their cement production. SCG emphasizes research and development in sustainable cement production and promotes waste-to-energy solutions for reducing landfill use.

Siam Cement Group is committed to using more alternative raw materials where possible and has set a target for waste-derived fuels in cement kilns to over 1.4 million tons by 2030, with a group-wide thermal substitution rate of 40%. They are also aiming to use by-products, such as slag and fly ash, at over 1.7 million tons per year

Conclusion

These activities show varying levels of engagement in cement recycling and the use of alternative materials across Southeast Asian countries. While some countries, like Singapore and Vietnam, are pushing forward with recycling initiatives involving by-products, others are still developing suitable infrastructure and knowledge to support widespread use of recycled cement and aggregate materials. Unfortunately, detailed data on the exact amount of cement being recycled in specific Southeast Asian countries is not readily available. However, the cement recycling initiatives vary considerably across different nations:

Overall, the cement industries in Southeast Asia are taking steps towards sustainability, but detailed statistics on cement recycling are largely unavailable, and activities vary widely in terms of scope and progress. For comprehensive data, country-specific industry reports or sustainability reports from leading companies might provide more detailed information.

In addition, compared to manufacturing volumes, there is still a big lack of capacity for recycling cement and little evidence of cooperating with existing research institutes outside of SEA or Thailand.

Appendix 1 Cement Recovery details

"Cement recovery" is a process where cement is extracted or reclaimed from old concrete to be reused in new construction materials. This is part of the broader concept of concrete recycling, and it aims to reduce the need for new cement production, which is an energy-intensive process that also results in high CO_2 emissions. Below, I outline the main methods and concepts associated with cement recovery:

1. Mechanical Processing

This approach involves breaking down waste concrete into smaller components, separating aggregate from the cementitious material. Cement recovery in this context is often about reclaiming the fine materials, which may include hydrated cement paste. Here's how this typically works:

Crushing and Milling: The waste concrete is first crushed, and then ground to recover the remaining unhydrated cement particles along with fine aggregates.

Screening and Classification: After grinding, the material is screened to separate fine particles, which may include unreacted cement that can still have some binding properties. This material can be reused in new concrete mixes.

2. Thermal Processing

Thermal methods are used to separate and recover cement from waste concrete. These methods involve heating the old concrete to break the chemical bonds within the hydrated cement paste, effectively de-calcifying it and converting it back into a reusable form.

Thermal Activation: In this process, concrete is heated to temperatures between 300°C and 600°C to induce changes in the hydrated cement, effectively breaking it down to create materials that can be reused as cementitious material.

Pyrolysis: Some studies have looked into using pyrolysis, a process where waste concrete is subjected to very high temperatures in an oxygen-free environment. This method decomposes organic components and breaks down the concrete to recover reusable components.

3. Chemical Processing

Chemical processing can be used to recover cement by dissolving and extracting components from waste concrete. This method typically involves the use of solvents or other chemicals to selectively dissolve hydrated cement phases, which are then re-precipitated for reuse.

Acid Leaching: A method where acids such as hydrochloric acid (HCl) or sulfuric acid (H_2SO_4) are used to dissolve components of hydrated cement. The extracted calcium can be re-precipitated as calcium hydroxide ($Ca(OH)_2$) and used again in cement production.

Alkaline Treatment: In some processes, waste concrete is treated with an alkaline solution, which helps to disintegrate the concrete matrix and separate cementitious components for reuse.

4. Re-carbonation

As part of cement recovery, carbonation is used to treat recycled concrete fines. In this method, the fines are exposed to CO_2 to form calcium carbonate ($CaCO_3$), which can act as a filler material in new cement mixes. This not only enhances the recycled material's properties but also serves as a carbon sequestration method, capturing CO_2 from the atmosphere. See also Appendix 2

5. Advantages of Cement Recovery

Reduction in CO_2 Emissions: Cement production is responsible for a significant portion of global CO_2 emissions. By recovering and reusing cement from waste concrete, it is possible to reduce the need for energy-intensive clinker production, thereby lowering overall CO_2 emissions.

Resource Conservation: Cement recovery allows the reuse of valuable raw materials such as limestone, reducing the need for new raw material extraction.

Cost-Effectiveness: Using recovered cement can reduce costs associated with raw materials and waste disposal, leading to more economically sustainable construction practices.

6. Current Challenges and Limitations

Quality of Recovered Cement: Recovered cement often does not match the performance characteristics of freshly manufactured cement due to impurities or altered chemical compositions.

Energy Requirements: Although the goal is to reduce CO_2 emissions, some of the thermal methods used for cement recovery require significant energy inputs, which may counterbalance the environmental benefits if not done efficiently.

Technical Complexity: Chemical and thermal methods for cement recovery are complex and require specialized equipment, making large-scale implementation challenging.

7. Practical Applications

Blended Cements: Recovered cement is often used in blended cement products, mixed with new clinker or other pozzolanic materials to create a binder suitable for non-structural or low-strength applications.

Supplementary Cementitious Material (SCM): In some cases, recovered cement is used as a supplementary cementitious material in concrete. This means it acts as a partial replacement for cement, contributing to the binding properties while improving sustainability.

8. Circular Economy Context

Cement recovery fits within the circular economy framework, which focuses on closing the loop on materials usage. Instead of disposing of construction and demolition waste, cement recovery aims to recycle this waste, reducing environmental impact and contributing to sustainable construction practices. This approach helps keep materials in the lifecycle longer, providing economic benefits and reducing the environmental burden associated with new cement production.

Examples of Projects and Research outside Thailand

European Cement Research Academy (ECRA) has been working on research projects focusing on the feasibility of cement recovery and recycling.

Japan and China have led various initiatives on recovering and reusing cementitious materials from demolition waste, driven by the need to reduce construction waste and greenhouse gas emissions.

In summary, cement recovery is an evolving field that contributes to making the construction industry more sustainable. Although there are challenges with energy consumption, quality, and technical requirements, ongoing research is helping to make this a more feasible option.

Appendix 2 Carbonation Process in Recycled Concrete

Carbonation is a natural chemical process where carbon dioxide (CO_2) from the atmosphere reacts with the calcium hydroxide ($Ca(OH)_2$) present in concrete to form calcium carbonate ($CaCO_3$). This process is an essential part of how recycled concrete can contribute to reducing CO_2 emissions and is also considered in the context of enhancing the properties of recycled concrete. The chemical reaction is as follows:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

This reaction can occur in two main contexts related to recycling waste cement:

1. Carbonation of Recycled Aggregates:

When waste concrete is crushed into aggregates for reuse, it can be exposed to CO_2. The exposed surface area of the aggregates makes them particularly receptive to carbonation.

The carbonation process forms $CaCO_3$ (calcium-carbonate), which not only helps sequester CO_2 but also strengthens the recycled aggregate, improving its properties for use in new concrete mixes.

This process is sometimes intentionally accelerated in a controlled environment to increase CO_2 uptake, known as accelerated carbonation. This helps to make the recycled aggregates more suitable for use in concrete production by improving their strength and stability.

2. Use of Carbonated Aggregates in New Concrete:

The $CaCO_3$ formed during carbonation improves the properties of recycled aggregates by reducing their porosity and enhancing durability. This helps mitigate some of the issues with recycled aggregates, such as higher water absorption compared to natural aggregates.

By incorporating carbonated aggregates into new concrete, the concrete benefits from improved mechanical properties and enhanced CO_2 sequestration, contributing to a more sustainable construction process.

Advantages of $CaCO_3$ Formation through Carbonation:

CO_2 Sequestration: One of the most significant benefits of carbonation is its ability to sequester CO_2, which is an important consideration in the context of climate change mitigation.

Enhanced Properties: The formation of $CaCO_3$ in recycled aggregates leads to increased density and reduced permeability, which improves the overall performance of recycled concrete in various structural and non-structural applications.

Environmental Benefits: Using carbonation in recycling processes supports a circular economy by reducing waste, improving the quality of recycled materials, and reducing the environmental footprint associated with cement production.

This carbonation process, with the subsequent formation of $CaCO_3$, is a key research area for enhancing the sustainability of recycled concrete. Accelerated carbonation is gaining interest as an effective way to improve recycled aggregates while also providing an environmental benefit through CO_2 capture.

Link to circular economy for products containing PU (polyurethane)

In addition this $CaCO_3$ is a so-called filler material in PU foam production. By adding calcium-carbonate, the finished PU foam will be more cost-efficient than pure PU foam. Obviously the usage of this filler material is impacting the physical properties of the PU foam, especially tensile strength, elongation at break and the hardness. In that sense it becomes less attractive for applications where comfort needs to be at prime.

Scientific research

1. *Van den Heede, P., & De Belie, N. (2012).* "Environmental impact and life cycle assessment (LCA) of traditional and 'green' concretes: Literature review and theoretical calculations."

This study provides a comprehensive evaluation of the environmental impact of recycled concrete compared to traditional concrete. The authors also discuss the possibilities of reusing waste cement in new concrete mixtures.

Publication: Cement and Concrete Composites, 34(4), 431-442.

2. *Kou, S. C., & Poon, C. S. (2009).* "Properties of concrete prepared with crushed fine stone, furnace bottom ash and fine recycled aggregate as fine aggregates."

This research focuses on the properties of concrete that contains recycled aggregates, including the performance of reused cement in concrete mixtures. It shows that recycled cement can be economically and technically viable for various applications.

Publication: Construction and Building Materials, 23(8), 2877-2886.

3. *Silva, R. V., de Brito, J., & Dhir, R. K. (2014).* "Properties and composition of recycled aggregates from construction and demolition waste suitable for concrete production."

This publication investigates the properties of recycled aggregates obtained from demolition waste, as well as the possibilities for reusing waste cement in new concrete. The research shows that recycled cement can be a viable option for construction projects with lower strength requirements.

Publication: Construction and Building Materials, 65, 201-217.

4. *Li, X. (2008).* "Recycling and reuse of waste concrete in China: Part II. Structural behaviour of recycled aggregate concrete and engineering applications."

This article describes the reuse of waste concrete and the performance of recycled concrete mixtures in structural applications. It also discusses the benefits and challenges of cement reuse in the Chinese construction sector.

Publication: Resources, Conservation and Recycling, 53(2), 107-112.

5. *Akbarnezhad, A., Ong, K. C. G., Tam, C. T., & Zhang, M. H. (2013).* "Economic and environmental assessment of deconstruction strategies using building information modeling."

This study examines how recycled cement and concrete can reduce costs and environmental impact in deconstruction projects. The focus is on how BIM (Building Information Modeling) can assist in evaluating reuse scenarios.

Publication: Automation in Construction, 37, 131-144.