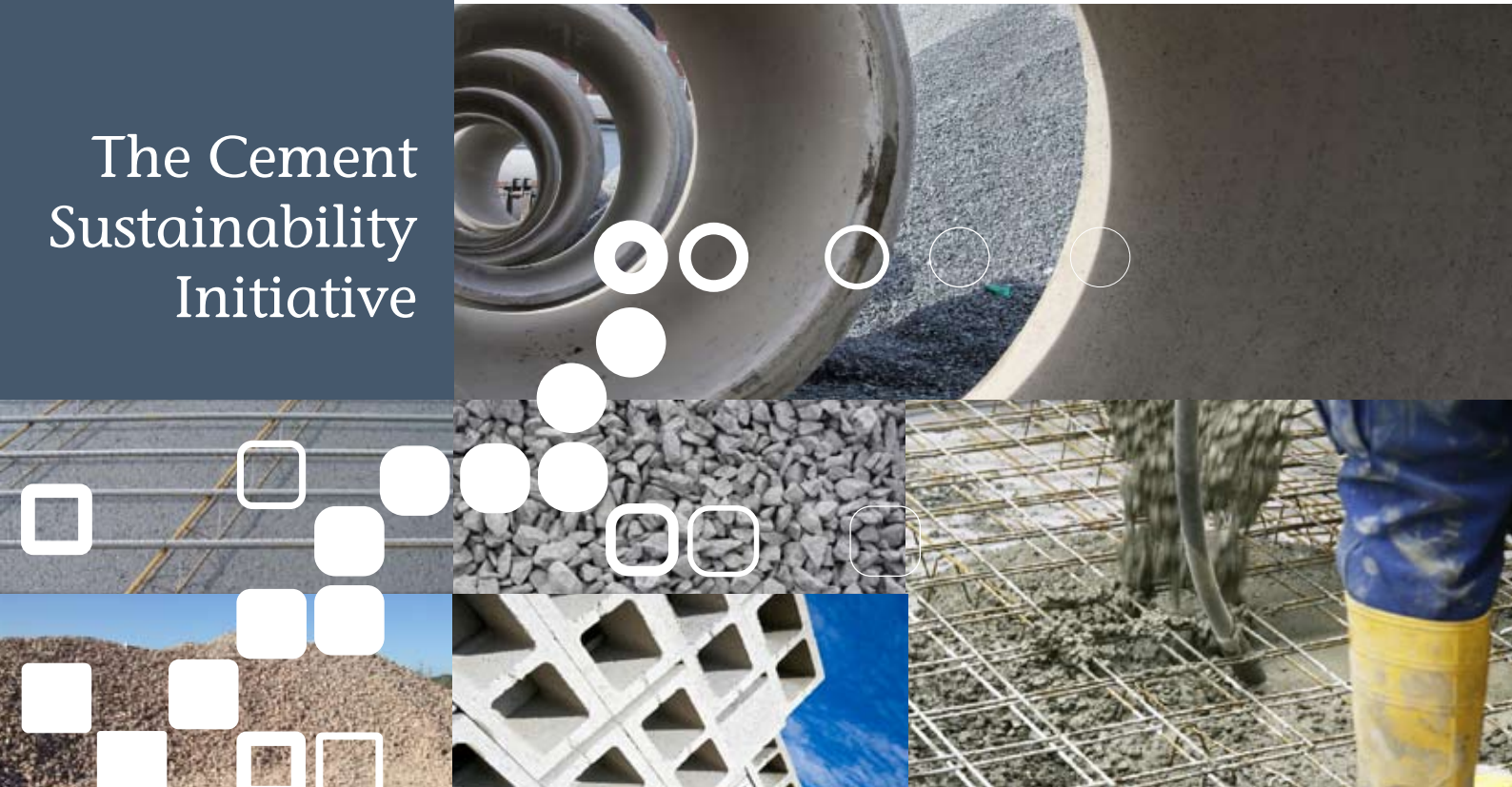


The Cement Sustainability Initiative



Recycling Concrete Executive summary





Introduction

Concrete is everywhere. It is the second most consumed material after water and it shapes our built environment. Homes, schools, hospitals, offices, roads and footpaths all make use of concrete. Concrete is an excellent material to make long-lasting and energy-efficient buildings. However, even with good design, human needs change and potential waste will be generated. Changes in infrastructure planning and needs result in the generation of construction and demolition waste (C&DW): an estimated 900 million tonnes every year in Europe, the US and Japan.

The Cement Sustainability Initiative (CSI) has been looking at the recycling of concrete as a component of better business practice for sustainable development. Concrete has fairly unique properties and its recovery often falls between standard definitions of reuse and recycling. Concrete is broken down into aggregate for use in a new life. This new life is usually road works aggregates, but in some areas it is also used as aggregates in new concrete. In some countries near full recovery of concrete is achieved. However, in many parts of the world the potential to recover concrete is overlooked and it ends up as unnecessary waste in landfill. Furthermore, concrete waste statistics are generally difficult to secure. This is partially explained by the relatively low hazard that the waste poses compared with some other materials, resulting in low public concern.

Recovering concrete has two main advantages: (1) it reduces the use of virgin aggregate and its associated environmental costs of exploitation and transportation; and (2) it reduces unnecessary landfill of valuable materials that can be recovered and redeployed. Recovering concrete, however, has no appreciable impact on reducing greenhouse gas emissions. In the product life cycle of concrete, the main source of carbon emissions is the cement production process (cement is added to aggregates to make concrete). The cement content in concrete cannot be viably separated and reused or recycled into new cement, and thus carbon reductions cannot be achieved by recycling concrete.

At present, most recovered concrete is used in road sub-base and civil engineering projects. From a sustainability viewpoint, these low-grade uses currently provide the optimal outcome in most circumstances.

With good initial planning and design of buildings, well considered renovation and managed demolition, the recovery and reuse of concrete is achievable and will contribute to sustainable buildings and urban societies of the future.

For the full report, go to www.wbcdcement.org/recycling

Recycling concrete reduces natural resource exploitation and associated transportation costs, and reduces waste going to landfill. However, it has little impact on reducing greenhouse gas emissions.

Twice as much concrete is used in construction around the world than the total of all other building materials, including wood, steel, plastic and aluminum.



Some myths and truths about concrete recycling

| Myths | Reality |
|--|--|
| <ul style="list-style-type: none"> • Concrete cannot be recycled | <p>Although concrete is not broken down into its constituent parts, it can be recovered and crushed for reuse as aggregate (for use in ready-mix concrete or other applications) or it can be recycled through the cement manufacturing process in controlled amounts, either as an alternative raw material to produce clinker or as an additional component when grinding clinker, gypsum and other additives to cement.</p> |
| <ul style="list-style-type: none"> • Recycled concrete aggregate cannot be used for structural concrete | <p>It is generally accepted that about 20% (or more) of aggregate content can be replaced by recycled concrete for structural applications.</p> |
| <ul style="list-style-type: none"> • Although some concrete can be recycled it is not possible to achieve high rates | <p>Countries such as the Netherlands and Japan achieve near complete recovery of waste concrete.</p> |
| <ul style="list-style-type: none"> • Concrete can be 100% made by recycling old concrete | <p>Current technology means that recovered concrete can be used as aggregate in new concrete but (1) new cement is always needed and (2) in most applications only a portion of recycled aggregate content can be used (regulations often limit content as do physical properties, particularly for structural concrete).</p> |
| <ul style="list-style-type: none"> • Recycling concrete will reduce greenhouse gases and the carbon footprint | <p>Most greenhouse gas emissions from concrete production occur during the production of cement. Less-significant savings may be made if transportation needs for aggregates can be reduced by recycling.</p> |
| <ul style="list-style-type: none"> • Recycling concrete into low-grade aggregate is down-cycling and is environmentally not the best solution | <p>A full lifecycle assessment should be undertaken. Sometimes low-grade use is the most sustainable solution as it diverts other resources from the project and uses minimal energy in processing. That is not to say more refined uses might not also suit a situation.</p> |
| <ul style="list-style-type: none"> • Recycled aggregate is more expensive | <p>This depends on local conditions (including transportation costs).</p> |

| Truths | Rationale |
|---|---|
| <ul style="list-style-type: none"> • Cement cannot be recycled | <p>Once cement clinker is made, the process is irreversible. No commercially viable processes exist to recycle cement.</p> |
| <ul style="list-style-type: none"> • Demolition concrete is inert | <p>Compared to other wastes, concrete is relatively inert and does not usually require special treatment.</p> |
| <ul style="list-style-type: none"> • Recycled concrete can be better than virgin aggregates for some applications | <p>The physical properties of coarse aggregates made from crushed demolition concrete make it the preferred material for applications such as road base and sub-base. This is because recycled aggregates often have better compaction properties and require less cement for sub-base uses. Furthermore, it is generally cheaper to obtain than virgin material.</p> |
| <ul style="list-style-type: none"> • Using recycled aggregate reduces land-use impact | <p>By using recycled aggregates in place of virgin materials (1) less landfill is generated and (2) fewer natural resources are extracted.</p> |
| <ul style="list-style-type: none"> • Recycling all construction and demolition waste (C&DW) will not meet market needs for aggregate | <p>Even near complete recovery of concrete from C&DW will only supply about 20% of total aggregate needs in the developed world.</p> |
| <ul style="list-style-type: none"> • Figures are not complete for recovery rates | <p>Data are often not available. When data are available different methods of counting make cross-country comparisons difficult.</p> |



Concrete – What is it made of and how much is there?

Concrete is made from coarse aggregate (stone and gravel), fine aggregate (sand), cement and water. Natural aggregates can be replaced by aggregates made from recycled concrete. Fly ash, slag and silica fume can be used as cementitious materials reducing the cement content. These materials can be added as a last step in cement production or when the concrete is made.

In the developed world most cement is made industrially into concrete and sold as ready-mix concrete. On a smaller scale, and more commonly in developing countries, concrete is made on the construction site by individual users.

Concrete can be recycled from:

- **Returned concrete that is fresh (wet) from ready-mix trucks**
- **Production waste at a pre-cast production facility**
- **Waste from construction and demolition.**

The most significant source is demolition waste.

Concrete

- **Concrete is the second most consumed material in the world after water**
- **Concrete forms the basis for much of today's urban environment**
- **An estimated 30 billion tonnes of concrete were consumed globally in 2006, compared to 2 billion tonnes in 1950**

How much waste is there?

Estimates for major regions include (in millions of metric tonnes per year):

| Amount of waste (Mt) | Europe | USA | Japan |
|--|------------|------------|-----------|
| Construction and demolition waste (C&DW) | 510 | 317 | 77 |
| Municipal waste | 241 | 228 | 53 |

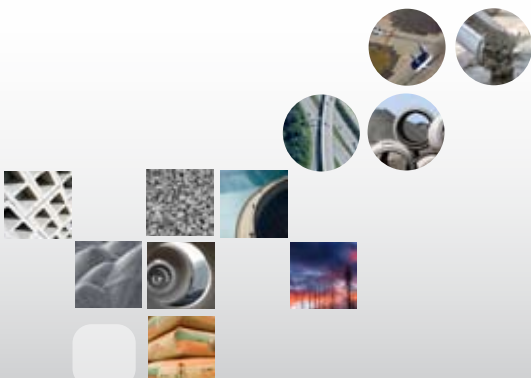
Sources: Eurostat; Construction Materials Recycling Association; Ministry of Land, Infrastructure and Transport of Japan; US EPA; Ministry of Environment of Japan.

Global data on waste generation are not available. Many countries do make construction and demolition waste estimates, a significant proportion of which is attributable to concrete (along with asphalt, wood and steel and other products in smaller quantities). There are vast regional differences due to construction traditions and the concrete content of construction and demolition waste can be anywhere from 20% to 80%.



Cement

- **5% to 20% of concrete is made up of cement**
- **95% of all manufactured cement is used to make various types of concrete**
- **Once concrete has been mixed, cement cannot be extracted from it for recycling**





How can recycled concrete be used?

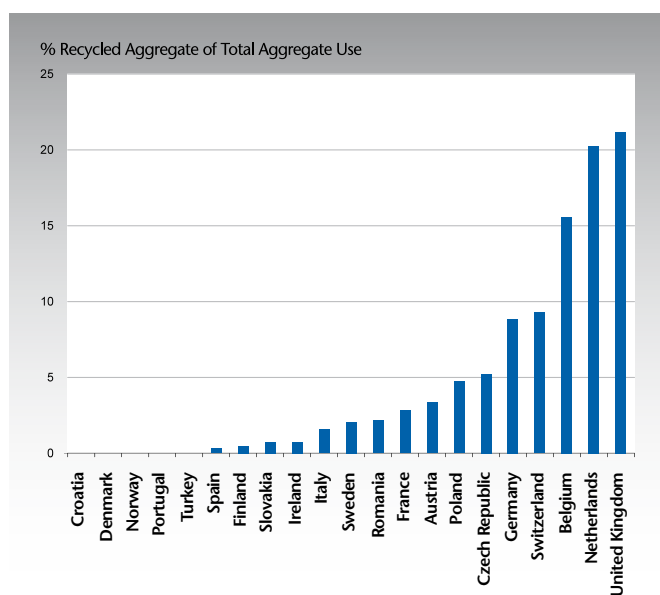
- ▶ **As aggregate** (coarse and fine and as fill material)
- ▶ **As blocks in original or cut-down form**

Use as aggregate

Most recycled concrete is used as aggregate in road sub-base.

When well cleaned, the quality of recycled concrete aggregate is generally comparable to virgin aggregate. The possibilities for use are equally comparable although the use of crushed concrete in new fresh concrete is rare.

Recycled aggregate accounts for ~6% to 8% of aggregate use in Europe, with significant differences between countries. The greatest users are the United Kingdom, the Netherlands, Belgium, Switzerland and Germany. In 2000 an estimated ~5% of aggregate in the US was recycled.



Source: UEPG 2005 and 2006 statistics published 2008

Use for road base, pavement and sub-base is widespread and the most common. In the US its use and acceptance has been promoted by the Federal Highway Administration, which has adopted a pro-use policy and undertaken research in the area. When used as a base and sub-base, recycled aggregate has been found to have superior strength to virgin aggregate, providing a very good construction base for new pavement. Various civil engineering projects can also use coarse aggregate.

For concrete

A common misperception is that recycled concrete aggregate should not be used for structural concrete. Australian government guidelines state that up to 30% of recycled aggregate can be used for structural concrete without any noticeable difference in workability and strength compared with virgin aggregate.

Significant potential for an increase in the use of coarse recycled aggregate in concrete remains. In some countries, notably Germany, Switzerland and Australia, concrete containing recycled aggregate is now being marketed and used. A notable example from Germany is the Waldspirale complex containing 105 residential dwellings designed by Friedensreich Hundertwasser in Darmstadt. Completed in 2000, the building makes use of recycled aggregate in the concrete.

To the extent that recycled aggregate is used in concrete, it tends to be mainly in ready-mix concrete.

Reuse in original form

Reuse of blocks in their original form, or by cutting them into smaller blocks, has even less environmental impact although only a limited market currently exists. Improved building designs that allow for slab reuse and building transformation without demolition could increase this use. Hollow core concrete slabs are easy to dismantle and the span is normally constant, making them good for reuse.

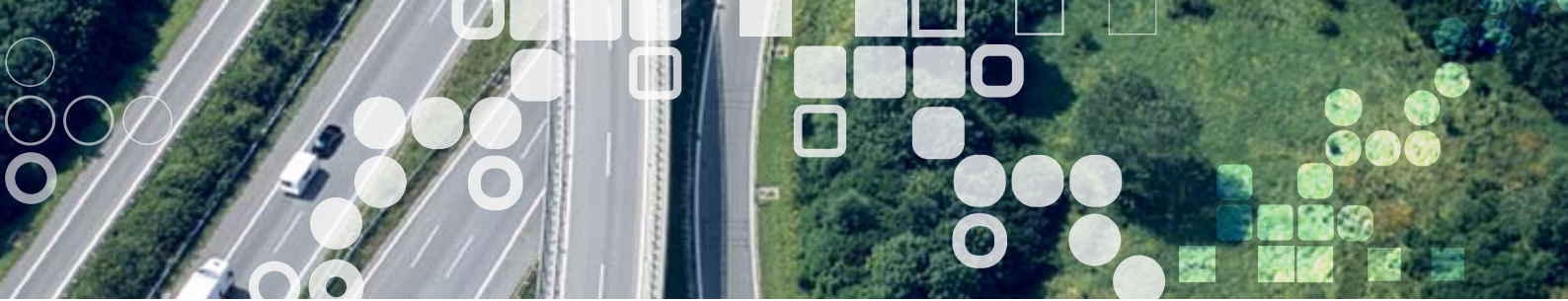
The quality of the recycled aggregate depends on the original material: demolition waste can present challenges

Concrete can be recycled from wastes from production, waste returned in ready-mix trucks, construction wastes and demolition wastes. Demolition waste is the most significant source, however this is also the most challenging source as (1) the concrete is usually mixed with other construction and demolition waste and (2) the makeup and history of the original concrete mix is less likely to be known. Strong building codes improve quality at all stages of use.

Current barriers and benefits for greater use of recycled concrete

Some key barriers and benefits include:

| Issue | Barriers | Benefits |
|---|--|--|
| Material cost vis-à-vis natural aggregate | Low economic cost of virgin aggregate in some countries. | Aggregates levies and transportation costs for natural aggregates can be higher. Overall project costs can be reduced as less landfill taxes/fees are paid on C&DW as the material is recovered instead of being landfilled. |
| Availability of material | Non-regular supply of C&DW. | C&DW is usually found in urban areas near construction and development projects. Virgin materials often need to be transported over greater distances. |
| Processing infrastructure | C&DW on-site waste management plans are needed. C&DW may need to be sorted. High-value recovered concrete requires costly processes. | Once infrastructure is established mobile sorting units and dedicated facilities can provide good returns. |
| Public attitudes | Misconception that recovered concrete is of lower quality. New materials are perceived as being of better quality. | Increasing environmental concerns leading to increased demand for eco-friendly products and reuse of materials. |
| Laws, regulations and industry accepted standards | Classification of recovered concrete as waste can increase reporting and permit requirements. Extra limitations can be placed on use. | Positive recycling laws, landfill taxes and green procurement policies by large users can all promote recycled concrete use. |
| Environmental impacts | Processing technology for recovery of concrete should consider possible air and noise pollution impacts as well as energy consumption, although there is little difference to natural aggregates processing. | <p>Within a life cycle analysis, use of recovered concrete can lower overall environmental impact.</p> <ul style="list-style-type: none"> • Failing to use recovered materials increases landfill and associated environmental and health costs • Failing to use recovered materials means virgin materials are used instead • Recovered concrete is generally inert • In some cases, transportation needs for recycled concrete can be lower than virgin materials (often not located in urban development areas) and as such fuel consumption, CO₂ emissions and road and vehicle use can be reduced. |
| Physical properties | For specialized applications (e.g. high performance concrete) there are some limitations on fitness for use. Technology can also limit recycling options. | For most uses, recycled concrete performs well. |



Green building design & practices

Today, the green building market is estimated to be a US\$ 12 billion industry in the US. The sustainable use of concrete in buildings encompasses several green building issues, namely:

1. Sustainability in initial design

Durable flexible designs improve the life of a building and allow future adaptations. Off-site prefabrication can be considered. Design for deconstruction should also be considered.

2. Optimum use of input materials in design

Reuse and recycling of materials can often be the optimal solution for sustainability. Concrete use can also improve building energy efficiency in some designs.

3. On-site waste management plans

These maximize the potential for materials reuse and recycling and minimize negative environmental and health effects. In particular, sorting can improve recovery and quality of recovered products.

Green buildings rating systems

The ability to maximize concrete recycling is influenced by the extent to which building codes and green rating schemes recognize concrete recycling. In general there are few legal restrictions on using recycled concrete as aggregate in building projects for filling, sub-base, asphalt and outdoor landscaping.

There are however often limitations on the amount that can be used in structural concrete. Often the main reason for limited use is misguided public perception with regard to the quality of recycled concrete or even a lack of consideration of the possibilities for its use. Green building schemes and rating systems can change this perception, especially if recycling concrete and using recycled concrete as a material is specifically addressed.

Well-known green building rating systems include LEED (USA), BREEAM (United Kingdom), CASBEE (Japan) and HQE (France), among others.

Recommendations

Concrete can be and is being recovered. The Cement Sustainability Initiative (CSI) supports initiatives targeted at an ultimate goal of “zero landfill” of concrete.

However, it needs to be noted that cement producers can only have an indirect role in supporting concrete recycling and the “zero landfill” goal. The CSI hopes that raising awareness of concrete recycling will promote discussion and encourage recycling of concrete by all stakeholders. Cement producers can be particularly involved with the work of subsidiaries in the concrete, aggregate and construction industries.

Towards the “zero landfill” of concrete goal, the following recommendations are made:

- Key stakeholder dialogue to develop reliable and consistent statistics
- Governments and other key players to publicize construction and demolition waste data
- Set targets for use in both road construction and building industries
- Develop economic incentives and legislation to allow infrastructure to develop and to promote concrete recycling
- Research and development to consider further recovery techniques and uses
- Green building schemes should further encourage good construction and demolition waste management and the use of recycled concrete aggregate
- Key stakeholder publicity to change public misconceptions

Stakeholder groups that can contribute to increasing concrete recycling rates include:

- Ready-mix manufacturers and aggregate producers
- Recycling enterprises
- Road builders
- Construction and demolition enterprises
- Building norms and standards bodies
- Local governments/town planners
- Waste regulators
- Trade associations
- Environmental agencies and NGOs
- Architects and Green building industry
- Research bodies and universities
- The consumers and the general public

CSI members



USA



Switzerland



Brazil



Italy



Mexico



France



Spain



Portugal



Spain



India



Portugal



Thailand



Ireland



Japan



Grasim Industries Limited

India



Greece

HEIDELBERGCEMENT

Germany



Brazil

About the WBCSD

The World Business Council for Sustainable Development (WBCSD) is a unique, CEO-led, global association of some 200 companies dealing exclusively with business and sustainable development. The Council provides a platform for companies to explore sustainable development, share knowledge, experiences and best practices, and to advocate business positions on these issues in a variety of forums, working with governments and non-governmental and intergovernmental organizations.

www.wbcscd.org

About the CSI

The Cement Sustainability Initiative (CSI) is a global effort by 18 leading cement producers. Headquartered in 14 countries, they have operations in more than 100 countries. Collectively, these companies account for about 30% of the world's cement production and range in size from very large multinationals to smaller local producers. All CSI members have integrated sustainable development into their business strategies and operations, as they seek strong financial performance with an equally strong commitment to social and environmental responsibility. Over its 10-year history, the CSI has focused understanding, managing and minimizing the impacts of cement production and use by addressing a range of issues, including: climate change, fuel use, employee safety, airborne emissions, concrete recycling and quarry management.

www.wbcscdcement.org

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