



# Cements for a low-carbon Europe

*A review of the diverse solutions applied by the European cement industry  
through clinker substitution to reducing the carbon footprint of cement  
and concrete in Europe*

CEMBUREAU - The European Cement Association based in Brussels is the representative organisation of the cement industry in Europe. Currently, its Full Members are the national cement industry associations and cement companies of the European Union (with the exception of Cyprus, Malta and Slovakia) plus Norway, Switzerland and Turkey. Croatia and Serbia are Associate Members of CEMBUREAU.

The Association acts as spokesman for the cement industry before the European Union institutions and other public authorities, and communicates the industry's views on all issues and policy developments with regard to technical, environmental, energy and promotional issues. Permanent dialogue is maintained with EU institutions, international authorities and other international associations.

Serviced by a multi-national staff in Brussels and with the input from its Members via four Working Groups as well as a number of Task Forces set up on an ad hoc basis and directly reporting to the appropriate Working Group, CEMBUREAU takes action in relation to all developments at European level affecting the cement industry.

CEMBUREAU plays a significant role in the world-wide promotion of cement and the ready-mix and precast concrete industries in co-operation with Member Associations and other relevant organisations. The Association regularly co-hosts conferences on specific issues aimed at improving the market perception of the concrete industry and promoting the use of generic cement and concrete products. In addition, the Association regularly commissions studies to evaluate specific issues of importance to the industry.

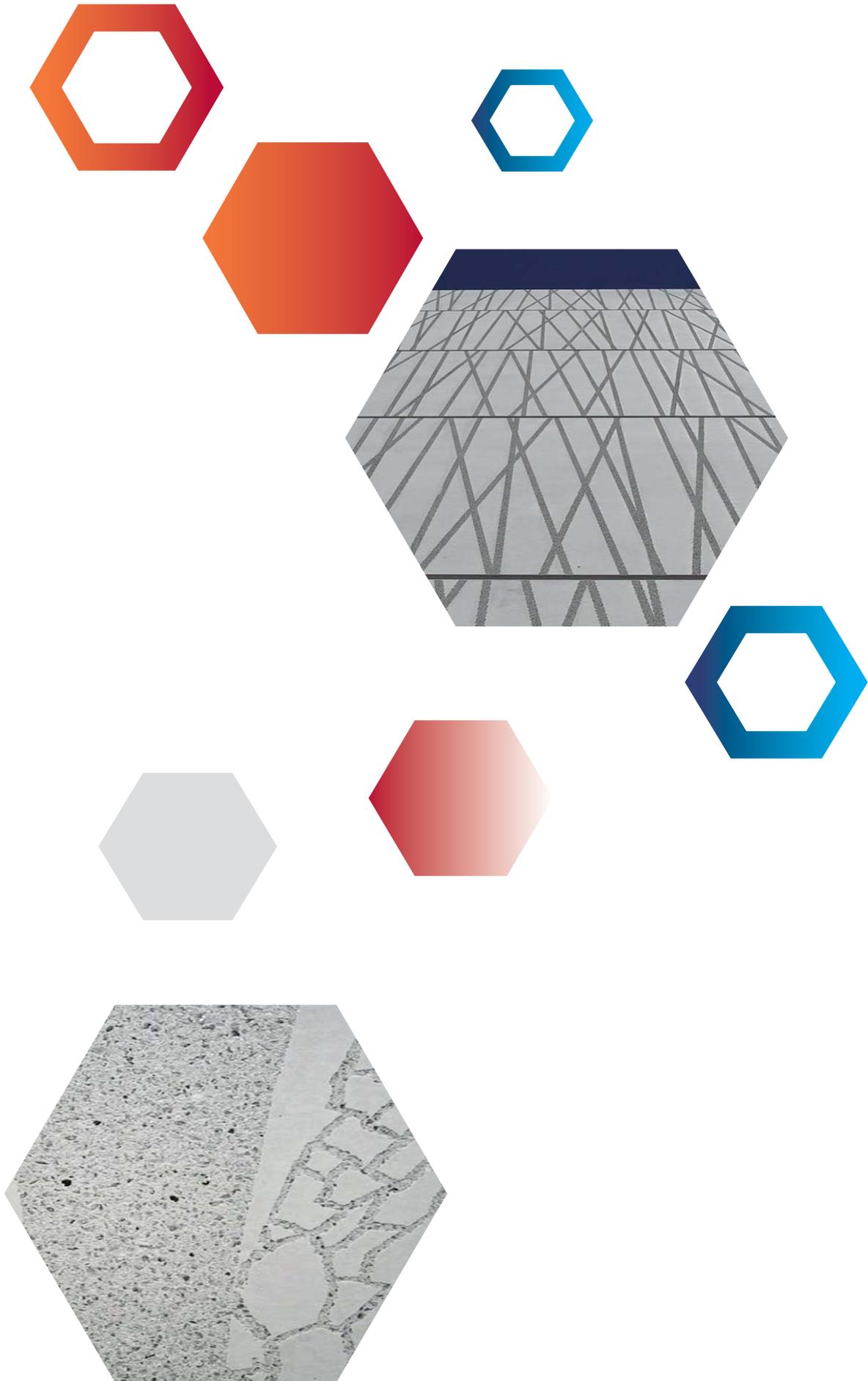




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# INTRODUCTION

## 1.1 Cement – the essential building material

Cement is the essential ingredient of concrete and mortar. These are the fundamental building materials required to provide our society with long-lasting, safe, comfortable housing and durable, robust, economic modern infrastructure.

The main constituent of cement is clinker. Clinker is produced from lime and silica bearing raw materials, such as limestone and clay, which are ground and fed into a rotary kiln. Clinker production takes place at temperatures around 1450°C where hydraulic calcium silicates and other compounds are formed. The clinker is then ground with gypsum and, increasingly in Europe, other additional materials (such as limestone, blastfurnace slag, coal fly ash and natural pozzolanic materials), leading to a fine homogenous cementitious powder which sets when water is added.

In concrete production, cement, aggregates (gravel, crushed rock, sand) and chemical admixtures are mixed with water. The water reacts with the cement to make a strong, water-resistant glue which binds the aggregates together. Concrete is an essential, virtually irreplaceable product used to construct the built environment. As a building material, concrete uses locally available mineral resources, contributes positively towards the energy efficiency of buildings due to its thermal mass, and has exceptional fire-resistance and durability properties. Concrete is also the only building material capable of making a significant contribution to mitigating the adverse affects of climate change through its use in flood-prevention schemes.

## 1.2 Cement and concrete in the built environment

Concrete can achieve significant energy efficiency when used in construction.

- Concrete can buffer a large proportion of heat gains in buildings. The high thermal mass of concrete decreases heating fuel consumption by 2-15% compared to equivalent lightweight constructions; this has been proven in research across the range of climates found in Europe.
- Concrete helps to prevent overheating in warmer climates, keeping buildings cool when temperatures rise, thus providing thermal comfort for users.
- Energy costs for artificial lighting can be reduced in infrastructural and building projects due to the light colour of exposed concrete surfaces.

- During the life of a concrete structure (such as a building or a road) the hydrated cement contained within the concrete reacts with the CO<sub>2</sub> in the air. This process is called concrete carbonation. As part of the CO<sub>2</sub> emitted during the cement production is reabsorbed by the cement through carbonation, this reaction is also referred to as cement recarbonation. The carbonation effect is enhanced when concrete is crushed and recycled.

## 1.3 The European cement industry's commitment to reducing its carbon footprint

While the lifecycle and durability benefits of cement and concrete can result in significant energy and CO<sub>2</sub> savings over the lifetime of buildings and structures, the cement industry is deeply committed to reducing emissions and other environmental impacts arising during the manufacture of cement. The industry is continuously developing more sustainable production processes and products.

The European Union is particularly advanced in recognising the importance of minimising emissions and, similarly, the European cement industry is working at company, country and European level together with CEMBUREAU to ensure all environmental impacts are minimised. In particular:



### Energy efficiency

Investment in state-of-the-art technologies in thermal and electrical efficiency has been a key element over recent decades of the cement industry's commitment to reducing its emissions in all greenfield developments and plant upgrades.

### Alternative fuels and raw materials

Co-processing of alternative fuels and raw materials in the cement industry provides a route to maximise substitution rates of non-renewable materials in EU industry. It has been recognised by the European Commission as a resource-efficient solution in its recent flagship initiative "A resource-efficient Europe"<sup>1</sup>.

- Alternative raw materials can be used to replace the natural raw materials extracted from quarries and used in clinker production. Examples include quarry overburden, contaminated soil and waste from road cleaning. The use of alternative raw materials has numerous benefits, not least the reduction in the use of primary raw materials, and thus meets the aims of the Raw Materials Initiative<sup>2</sup>.
- Alternative fuels (see charts below) offer a high potential for the cement industry to reduce global CO<sub>2</sub> emissions. Without co-processing, the waste which replaces primary fuels (such as coal, heavy fuel oil and gas) would have to be landfilled or incinerated, with corresponding greenhouse gas emissions. Examples of alternative fuels include biomass, used tyres and waste oil.

### Lower-clinker cements

In addition to reducing the environmental impact of the clinker production process through the two levers noted above, the clinker content of cement can be reduced significantly by the use of other main constituents such as limestone, blastfurnace slag, coal fly ash, and natural pozzolanic materials, based on regional availability.

- These constituents are defined in the European cement standard EN 197-1 "Cement – Part 1: Composition, specifications and conformity criteria for common cements". In many cases, several main constituents are combined. On average, in CEMBUREAU member countries the use of cements with a low clinker content is growing steadily.
- At an equivalent performance level, the choice of a cement with a low clinker content using materials with latent cementitious properties, provided that these materials are available locally, is currently seen as a choice that reduces the initial environmental impact of concrete construction.

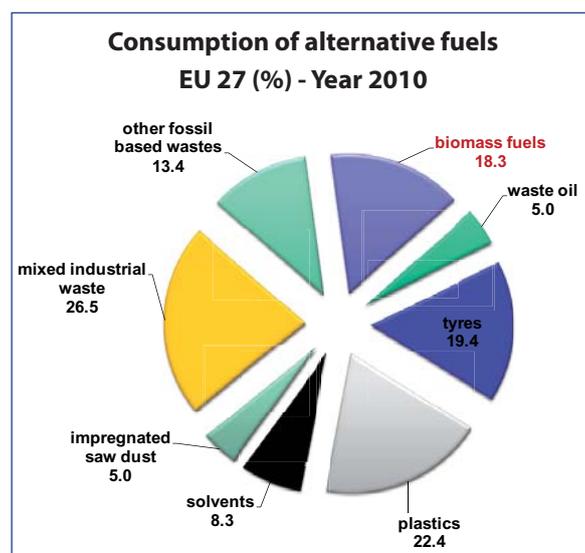
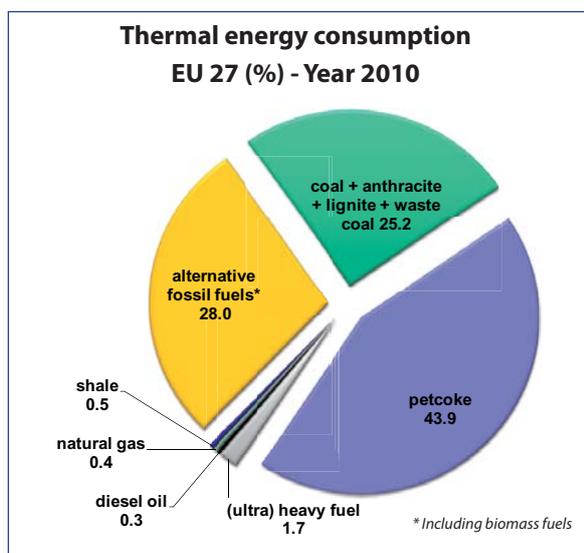
In addition, innovative binder technologies not requiring the high temperature firing of limestone and silica materials are being researched. This research is at an early stage and significantly more time and work will be required to identify whether they are economically viable and suitable for the production of durable concrete.



### Carbon capture

Carbon capture and storage is currently being researched by the cement industry. Although not proven on an industrial scale, research on carbon capture (post-combustion and oxyfuel technologies) is being undertaken by the European Cement Research Academy (ECRA) to identify the possibilities it has to offer.

This publication focuses on the diverse solutions applied by the cement industry across Europe to reduce the carbon footprint of its products through the production of low clinker cements, while meeting the composition and performance requirements of the European cement standard EN 197-1 for common cements. The reason for the diversity of the solutions identified and applied is associated with two factors: the availability of suitable materials, which varies from country to country and from region to region, depending on the local geology, and the proximity of industries producing alternative materials which can be beneficially utilised by the cement industry.



Source: WBCSD CSI "Getting the Numbers Right"

<sup>1</sup> A resource-efficient Europe – Flagship initiative of the Europe 2020 Strategy: <http://ec.europa.eu/resource-efficient-europe/>  
<sup>2</sup> On 2 February 2011 the European Commission adopted a new strategy document on non-energy raw materials which sets out targeted measures to secure and improve access to raw materials for the EU: <http://ec.europa.eu/enterprise/policies/raw-materials/>





# EUROPEAN STANDARDS FOR CEMENT AND CONCRETE

## Cement

The European cement standard EN 197-1 "Cement – Part 1: Composition, specifications and conformity criteria for common cements" defines 27 distinct common cement products and their constituents. The standard includes requirements for the constituents and performance requirements in terms of mechanical, physical and chemical parameters for the 27 products. The standard defines three standard strength classes at 28 days (32,5, 42,5 and 52,5). In addition, three early strength classes are included for each standard strength class: one for low early strength, one for ordinary early strength and the third for high early strength.

The 27 products are grouped into five main cement types as follows:

- CEM I Portland cement (clinker > 95%)
- CEM II Portland-composite cement (65%–94% clinker)
- CEM III Blastfurnace cement (5%-64% clinker)
- CEM IV Pozzolanic cement (45%-89% clinker)
- CEM V Composite cement (20%-64% clinker)

## Concrete

The European concrete standard EN 206-1 "Concrete – Part 1: Specification, performance, production and conformity" applies to concrete for structures cast in situ, precast structures, and structural precast products for buildings and civil engineering structures. The concrete may be mixed on site, ready-mixed or produced in a plant for precast concrete products. The standard specifies requirements for the following:

- The constituent materials of concrete
- The properties of fresh and hardened concrete
- The limitations for concrete composition.

EN 206-1 is a voluntary rather than a harmonised standard. Where general solutions have not been agreed across Europe, the relevant clauses permit the application of National Standards or provisions valid in the place of use of the concrete.

CEN members, through their national application of EN 206-1, outline, in a National Annex, rules based on historical experience for the use of cements in concrete for specific applications. These rules also, in many cases, extend to the use of various additions (inorganic materials) with cements deemed appropriate for specific applications.

Different climatic conditions, raw materials availability and experience have led to significant differences in standards, regulations and practices in local and regional markets as to which cement types can be used for specific applications. This is due to historical knowledge of the performance of cements in the diverse applications and climatic conditions found across Europe.

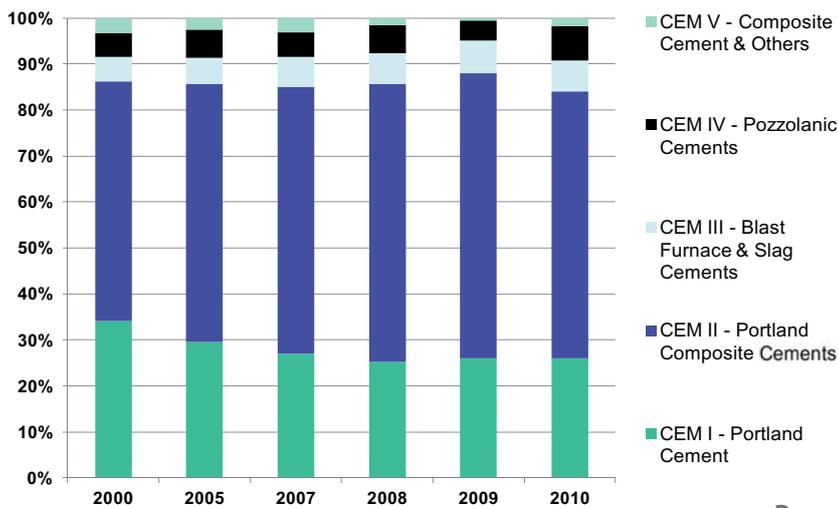




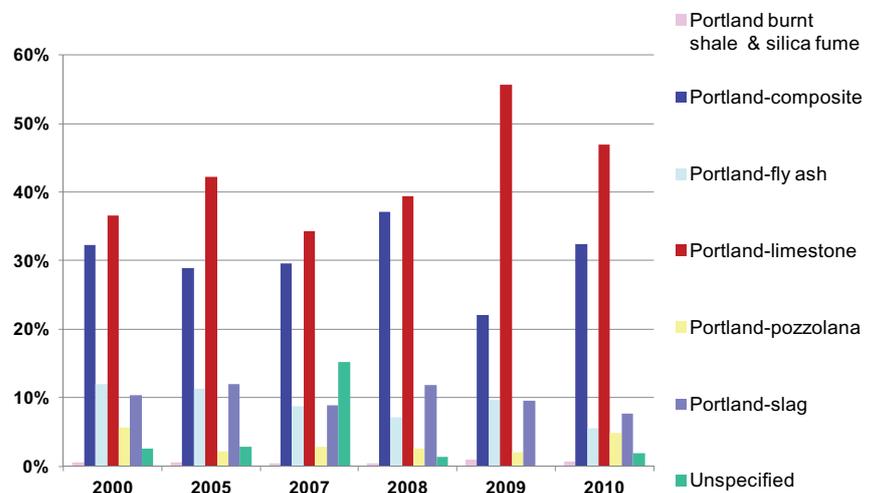
# MARKETS - EVOLUTION OF CEMENT COMPOSITION ACROSS EUROPE

The evolution in cement composition, clearly demonstrating the reduction in clinker content, is shown in Figures 1 and 2 below. The most common alternative constituent is limestone.

**Domestic deliveries by cement type**  
CEMBUREAU 2000 - 2010



**Domestic deliveries of CEM II sub-type**  
CEMBUREAU 2000-2010



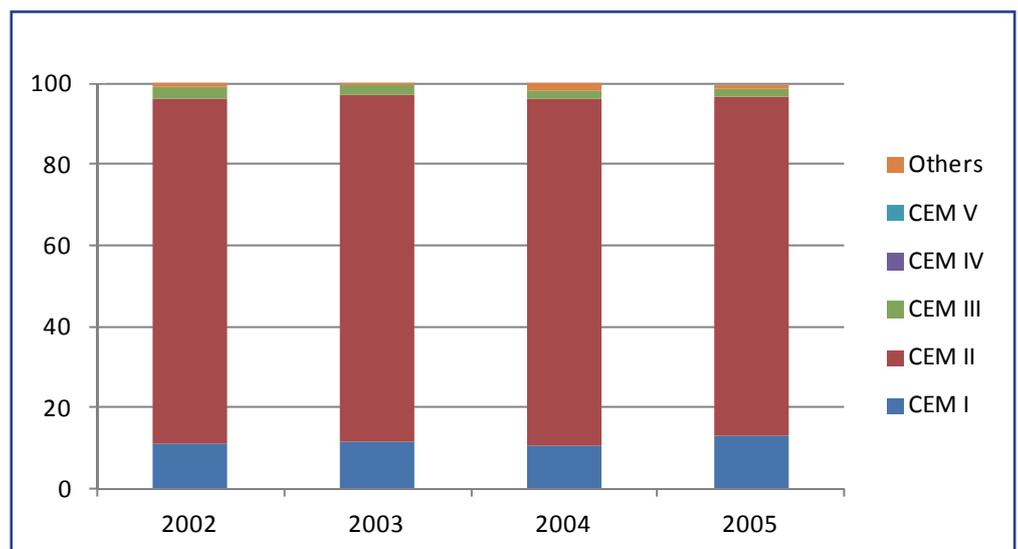
Note: Does not include data for Slovak Republic and Cyprus for all years (non members of CEMBUREAU). No cement production in Malta. Year 2008 does not include data for Bulgaria, Denmark, France and Poland





## EXAMPLES OF THE EVOLUTION IN USE OF LOWER CLINKER CEMENTS IN SOME EUROPEAN COUNTRIES

### Austria

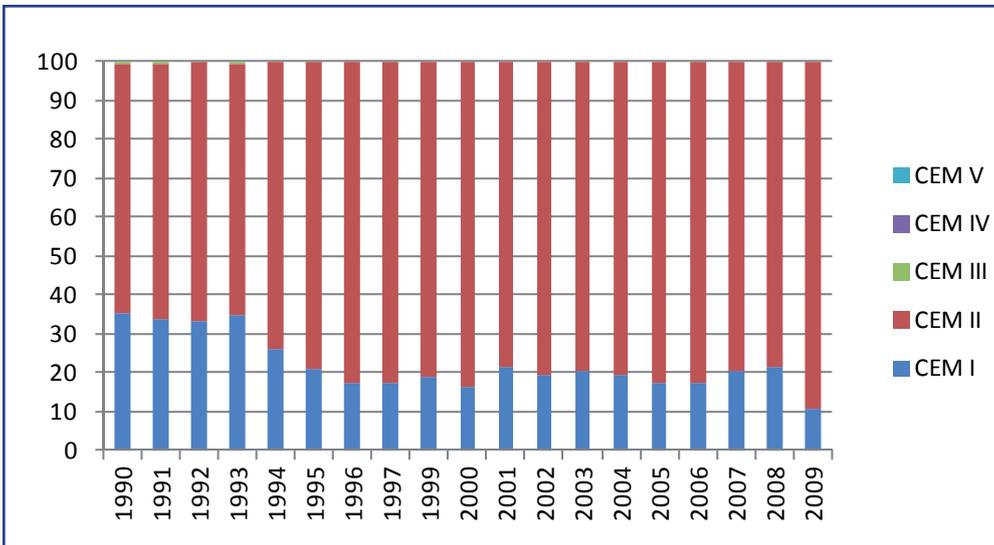


Austria has been using what is currently referred to as CEM II/A cement for more than 60 years for ready-mixed and precast concrete as well as shotcrete. In order to reduce its CO<sub>2</sub> emissions, the Austrian cement industry started to investigate the performance of cements with a lower clinker content in 2007. This is the largest ongoing project of the Austrian Cement Association, counting on the participation of all Austrian cement producers. The availability of hydraulic or pozzolanic materials like slag or fly ash is limited and their future is uncertain. Therefore, in Austria, the trend is moving towards cements with a higher limestone content: CEM II/B-M.



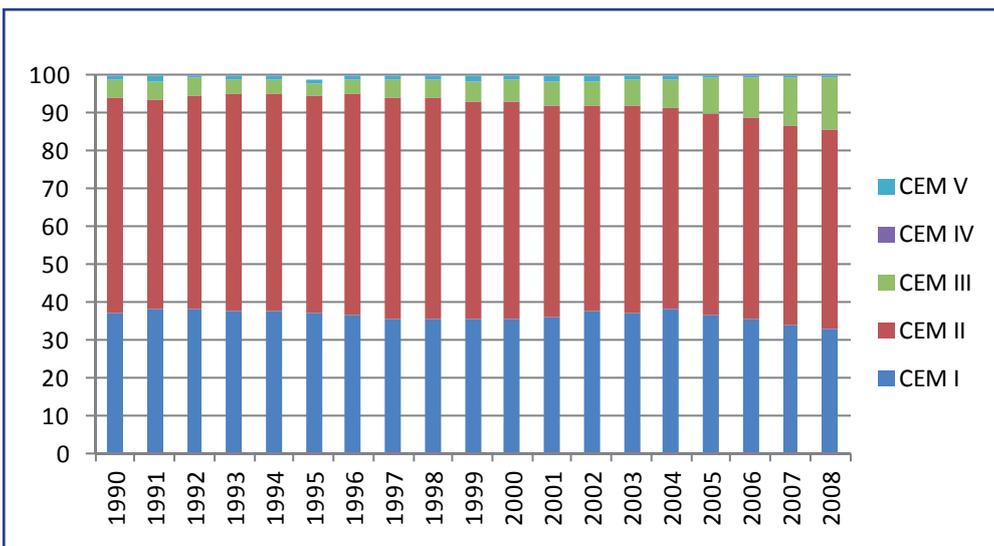


## Finland



CEM II/A cement (CEM II/A-M /S-LL 42,5 N with a market share of around 40–45%, and CEM II/A-LL 42,5 R with a share of 35–40%) has been the main type of cement used in Finland for decades. The market share of CEM I cements has decreased from 33% in 1990 to just over 10% in 2009. In 2006 a new cement type, CEM II/B-S, was introduced, but, due to limited grinding capacity, coupled with high cement demand, production of this cement stopped in 2007. In 2009 test production of a new cement type, CEM II/B-M (S-LL), began. This cement was only brought onto the market at the beginning of 2010.

## France

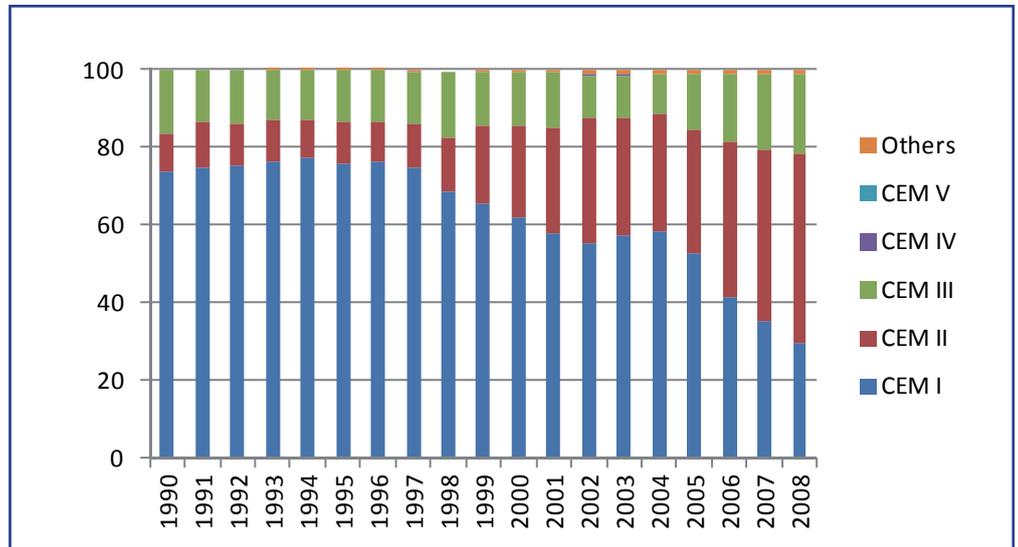


Production and use of cements made from one or more constituents other than Portland cement clinker have a long history in France. Blastfurnace cements have been manufactured since 1890 and standardised before the end of the nineteenth century. Cements corresponding to Portland composite cements CEM II/A-S, CEM II/A-V and CEM II/A-P were standardised in 1959, with the addition of CEM II/A-M (S-V) in 1964. In 1974, cements corresponding to CEM II/A and CEM II/B were defined in the French standard with the possible use of one or more constituents selected from a list comprising blastfurnace slag, fly ash (siliceous and calcareous), pozzolana (natural and natural calcined), and limestone. Within a couple of years, Portland limestone cement became the most common cement type in France for the production of structural concrete mainly dedicated to housing works. In 1989, cement types other than CEM I represented two thirds of a production volume of 24 million tonnes, with cements equivalent to CEM II accounting for more than 60% and cements corresponding to CEM III and CEM V accounting for nearly 6%. In 1994, all cement compositions covered by ENV 197-1 of 1993 were incorporated within a revision of the French cement standard. Since 1989, the proportions of the five main types of common cements has remained almost stable but, since the mid-nineties, a slight but continuous increase of the proportion of CEM III and CEM V has been seen.



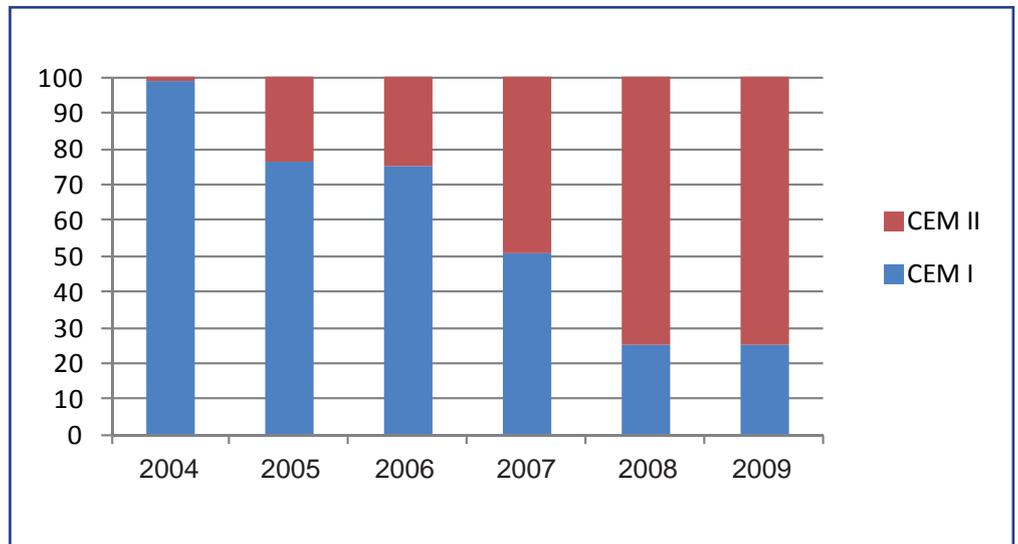


## Germany



The use of cements with several main constituents has a long and successful tradition in Germany. CEM II-S Portland-slag cements and CEM III blastfurnace cements have been industrially produced for more than a century, and they have also been standardised for almost 100 years. Nowadays, CEM III/A blastfurnace cements are used as standard cements in some regions for producing ready-mixed concrete for civil engineering and building construction. CEM II/A-LL Portland-limestone cements have been produced and used in concrete in Germany since the beginning of the 1980s. In some regions of Germany, in particular, CEM II-T cements are important. To continue reducing CO<sub>2</sub> emissions, several German cement producers have developed and launched Portland-composite cements CEM II/A-M and CEM II/B-M in accordance with EN 197-1 since 2005. In most cases, these cements are of the types CEM S-LL, CEM V-LL or in some regions CEM T-LL. In 2009, CEM II-M cements had a market share of 10%. The clinker-to-cement factor, which could be seen as an indicator for the CO<sub>2</sub> emissions of the cement industry, was reduced from 0.86 (2000) to 0.75 (2009).

## Ireland

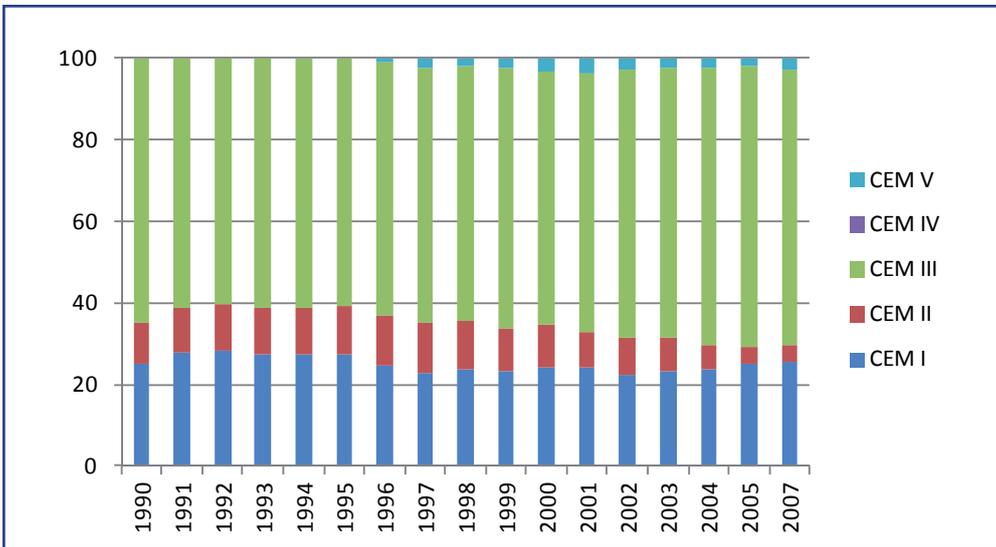


CEM I cements have been the predominant cements used in Ireland since the foundation of Ireland's cement industry in the late 1930s. Product consistency and high quality have contributed to a reliance on concrete, using CEM I, throughout the construction sector until recent times. Ireland's cement manufacturers have been responsible for a revolution in the cement market since 2004. In that year CEM II cements were launched with a concerted effort by the industry to provide assurance with regard to the technical and performance aspects of CEM II. Now CEM II/A-L and CEM II/A-V cements using locally available materials account for more than 80% of cement sales in Ireland. The cement industry's goal with the introduction of CEM II cements was to improve the sustainability of cement products, while maintaining traditional strength and durability performance. Eco-efficient CEM II cements represent one component of the industry's carbon reduction strategy.

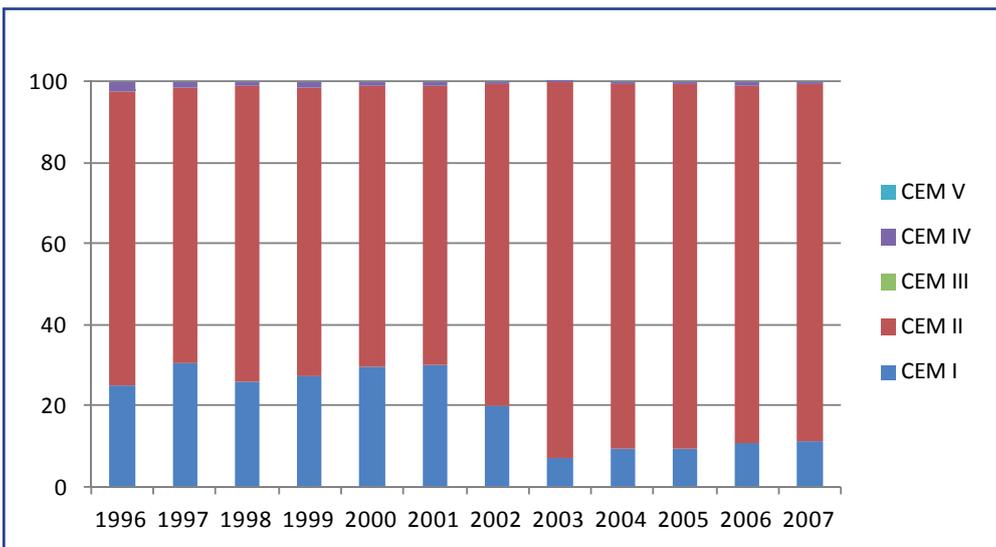




## The Netherlands



More than a hundred years' experience with blastfurnace slag cement (CEM III) has clearly demonstrated that structures made with this cement can be durable even under the harshest of marine conditions. For over 60 years marine structures have been built exclusively with blastfurnace slag cement. Although it is used in The Netherlands as a multipurpose cement for all concrete products, it is in marine applications that its benefits in comparison with Portland cement (CEM I) are most obvious. Especially favourable are its properties with respect to the protection of steel reinforcement against chloride-initiated corrosion, its sulfate resistance and its behaviour in combination with alkali-silica reactive aggregates.



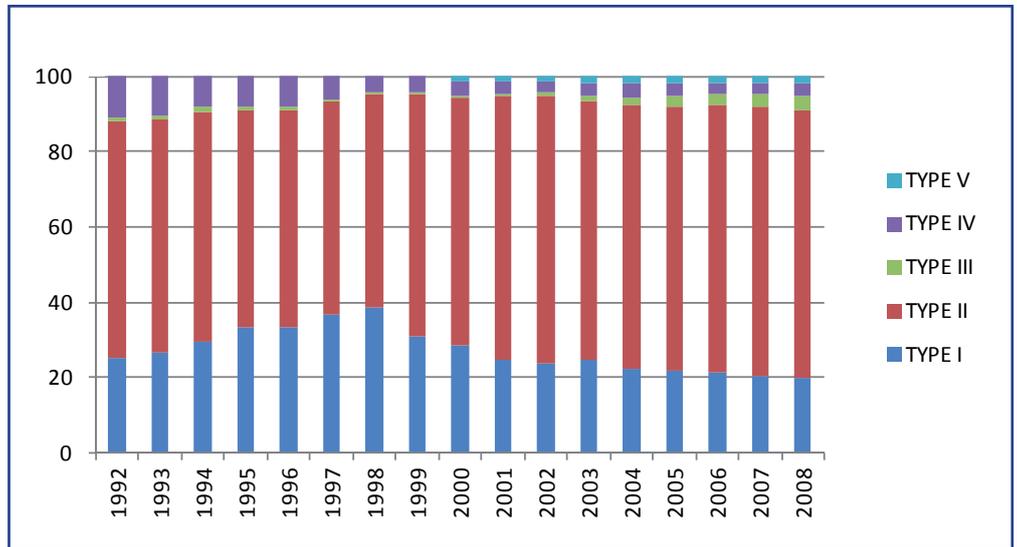
## Portugal

Over the past decade, in order to increase the production of low carbon cements, the cement industry has mainly focused on the introduction of lower clinker cements in high performance concretes for ready-mixed and precast concrete. The precast and ready-mixed concrete industries have traditionally used CEM I cements for high performance concretes, which fulfil all the regular requirements of different concrete applications. The cement industry began to study CEM II/A cements in 2001. In 2002/2003 CEM II/A-L production began and communication/promotion actions were undertaken. After an initial reluctance towards adopting a new type of cement, the use of CEM II/A-L quickly spread. Today, lower clinker cements represent around 90% of Portuguese cement consumption. Nevertheless, Portuguese cement companies plan to make the industry even more sustainable and are currently launching CEM II/B-L, class 42,5. However, maximising the use of lower clinker cements remains a major challenge in Portugal, as there is no slag available and coal fly ash availability tends to be limited. This will lead the industry towards increasing its use of limestone as a main constituent in cement.



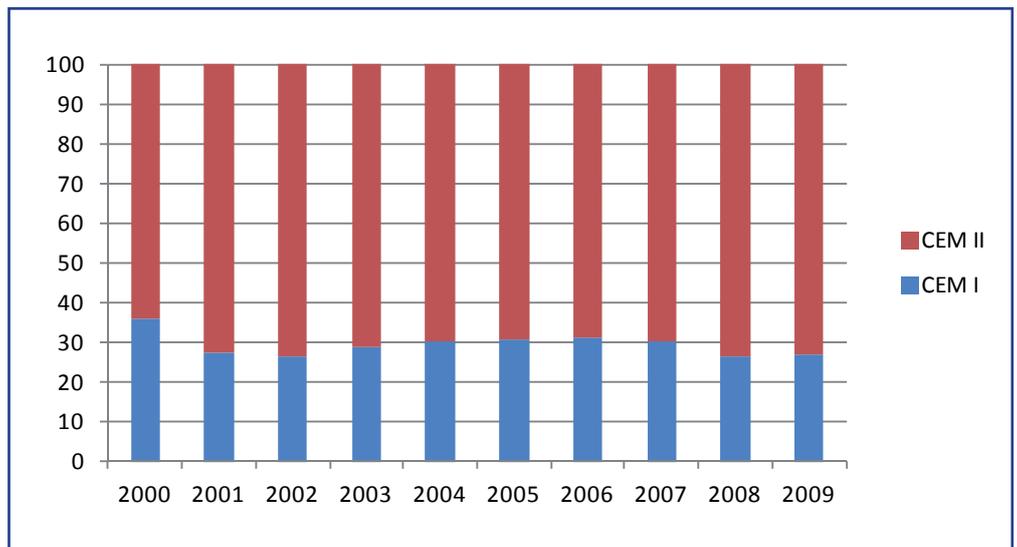


## Spain



Cement production has a long and successful tradition in Spain since 1898. Up until the 1970s, CEM I was the cement used in the Spanish construction industry. Since then, other cement types have been increasingly used. Regarding cement production by types, CEM II currently represents 69.8% of total production, with CEM II/A-V 42,5 R accounting for the largest portion in 2009, followed by CEM II/A-L 42,5 R. The production of CEM I 52,5 R was also relevant during 2009. In 2009, the share of the total cement production for each cement type (compared to 2008) has remained fairly constant, although with some exceptions. Regarding the evolution of production by cement type, CEM I accounted for 30% of production ten years ago whilst it currently accounts for approximately 20%. CEM II has grown from 65% in 1999 to nearly 70% (69.8%) in 2009. On the other hand, CEM V, which was not produced in 1999, represented 1.4% of the market in 2009.

## Sweden

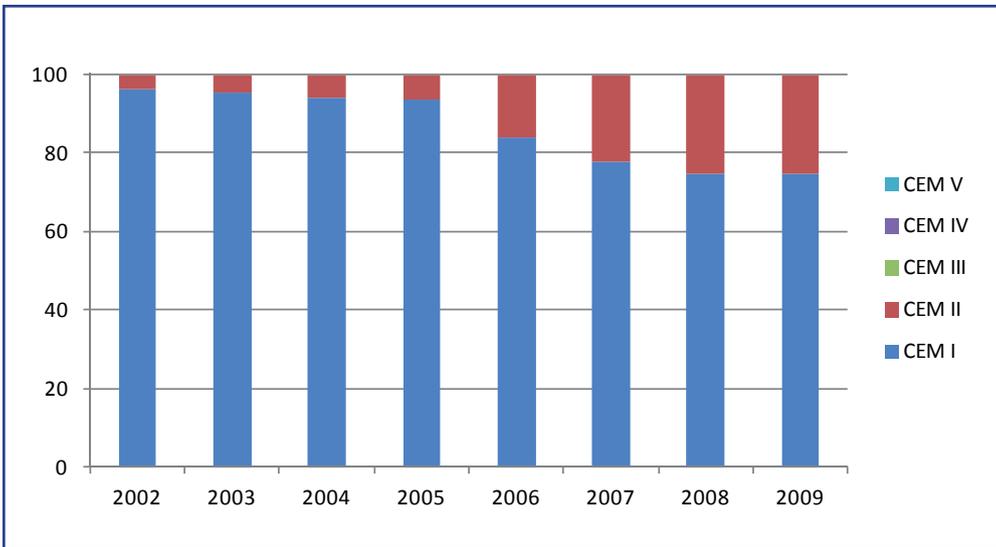


Following unsuccessful attempts to introduce both slag and fly ash cements during the early 1980s, at the end of 1999/beginning of 2000 a new cement type (CEM II/A-LL 42,5 R) was successfully placed on the Swedish market. The aim was to completely replace CEM I 42,5 R, which was the standard product for normal building structures. The cold Swedish climate and high pace of building construction meant that changing to a cement with a lower clinker content could be achieved successfully only through demonstrating evidence of equal performance. The new cement was therefore designed to obtain the very same or better properties as CEM I in terms of the early strength and durability, especially frost resistance, of the concrete. For civil engineering structures, the use of the existing special CEM I with moderate heat, sulfate resistance and low alkali properties continued. The Swedish Transport Administration (Trafikverket) prescribes the use of CEM I with additional properties for road, bridge and tunnel construction. The Swedish national amendment to the European concrete standard (SS 13 70 03 Concrete) is rather restrictive when it comes to the use of cements with a low clinker content. However, in the present version, both CEM I and CEM II/A are accepted in the most severe exposure classes, but not CEM II/B with a clinker content between 0.80 and 0.65. Today CEM II/A-LL 42,5 R is a well-established basic cement for all normal building structures in Sweden.





## United Kingdom



Composite cements have been available in the UK for over 90 years in some local markets. Over the past five years the range of cement types has increased, where the cements contain limestone, fly ash or blastfurnace slag, and are generally available across the whole of the UK in bags or in bulk. In addition, the UK has a tradition of combining CEM I with either ground granulated blastfurnace slag (ggbs) or fly ash within the mixer used for the production of concrete. This also makes a significant contribution to the overall reduction in clinker consumption that is not evident from statistics relating only to factory-made cement production.





## PRACTICAL EXAMPLES

Title	<b>Art Museum – Bregenz</b>
Country	<b>Austria</b>
Type of structure	<b>Museum</b>
Cement type	<b>CEM II/A – S 32,5 R</b>



For the construction of the light-coloured concrete building of the Art Museum of Bregenz, the colour and quality of the concrete necessitated special attention. In order to meet quality requirements, the concrete mix was defined, the quantity of aggregates and cement needed for the whole project were batch produced and the construction process was carefully controlled. The thermal mass of the concrete allowed for the partial replacement of air conditioning systems, making the building more environmentally friendly.



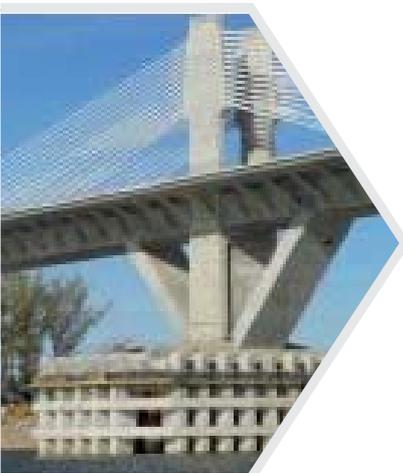


Title	<b>Rehabilitation of the Antwerp Ring Road</b>
Country	<b>Belgium</b>
Type of structure	<b>Urban motorway (ring road)</b>
Cement type	<b>CEM III/A 42,5 N LA</b>



The R1 is a 14-km ring road which surrounds the city of Antwerp and was opened to traffic in 1969. The road was first rehabilitated between 1976 and 1977, with some sections of the road being widened to up to 7 traffic lanes. However, an increase in traffic intensity to nearly 200 000 vehicles per day led to the need for a complete structural rehabilitation of this motorway. After a thorough comparative study of the different alternatives, the main part of the existing pavement was replaced with a new pavement structure consisting of 23 cm of continuously reinforced concrete supported by a 5 cm thick bituminous asphalt inter-layer, 25 cm of cement-stabilised asphalt rubble and 15 cm of recycled crushed lean concrete. A fine-textured exposed aggregate concrete surface (0/20 - nominal aggregate size is 20 mm - concrete with cement content of 400 kg/m<sup>3</sup>) was applied in order to obtain an excellent skid resistance combined with a reduction of the rolling noise. Since the mid-nineties, the standard construction method for concrete roads in Belgium has been paving in continuously reinforced concrete with a thickness of 23 cm and a chemically exposed aggregate surface finish. The concrete road surface is laid in a single run of a slipform paver. This method is simple and reliable. A suitable macrostructure is required to obtain a low-noise road surface, i.e. the uniform distribution of fine stones – up to approx. 10 mm in grain size – on the concrete surface. This is taken into account, in the concrete composition, by imposing a maximum aggregate grain size of 20 mm and by keeping the content of fine stones (fraction 4/6.3) high, i.e. 20% to 25% of the sand/stone mixture.

Title	<b>Vidin-Calafat Bridge</b>
Country	<b>Bulgaria–Romania</b>
Type of structure	<b>Bridge/railway</b>
Cement type	<b>CEM III/A 42,5 N</b>



The Vidin-Calafat Bridge (also known as Danube Bridge 2) is a road and railway bridge linking the cities of Calafat (Romania) and Vidin (Bulgaria). This bridge is of key significance not only for the development of the Pan-European Transport Corridor IV but also for the entire South-East European Transport Axis and the Trans-European Transport network. The bridge will have a significant impact on the development of the region as, on average, about 980 jobs are due to be created, with around €60 million being directly invested in the local and regional economy. On the Bulgarian side, the road and railway bridge will include four traffic lanes, one single railway track, a bicycle lane and two pavements for pedestrians and services. In addition, a new freight railway station, 7 km of new railway line as well as 7 new two-level road junctions will be built, and an existing passenger station will be rebuilt. On the Romanian side, the project includes the construction of 5 km of new railway line, 5 km of road and a terminal station for joint border control and automobile transport toll charging. CEM III/A 42,5 N was chosen as it has lower heat of hydration compared to ordinary Portland cement and an increased resistance to aggressive environments especially with high sulfate content. The applied concrete has a very low permeability, high density and strength.





Title	<b>Precast concrete elements</b>
Country	<b>Denmark</b>
Type of structure	<b>Housing and Industry</b>
Cement type	<b>CEM II/A-LL 52,5 R</b>



Cement which is used for precast concrete element production preferably has a high early strength to enable short production cycle times at the plant. A CEM I cement would, therefore, traditionally be the preferred cement type. In order to achieve a high early strength, this may lead to a higher clinker content in the concrete than needed to achieve the required 28 day strength and durability. A high early strength limestone cement has therefore been developed in Denmark for this market segment. This cement is allowed for all applications and in all environmental classes except for swimming pools, marine constructions and certain chemically aggressive environments (exposure class XA3). Today, CEM II/A-LL is, therefore, the preferred cement type for the production of precast concrete elements in Denmark.

Title	<b>New CEM II B-M cement in a bridge in Turku</b>
Country	<b>Finland</b>
Type of structure	<b>Bridge</b>
Cement type	<b>CEM II/B-M (S-LL) 42,5 N</b>



The newly developed CEM II/B-M (S-LL) 42,5 N cement was used for the construction of a road bridge in Käärmekallio near Turku airport, commissioned by the city of Turku. The casting of the bridge deck was done in warm weather with an outdoor temperature of up to around 30°C. A CEM II/B cement was chosen in order to limit the maximum temperature and temperature differences in this relatively massive construction. Around 2 000 m<sup>3</sup> of concrete was used. As freezing temperatures and temperature cycles of around 0°C are common in the Turku area and the roads are salted during winter time, special attention was given to the concrete's resistance to freeze-thaw with de-icing salt. The P-factor (which is the index used to evaluate the frost resistance of the concrete) was calculated according to Finnish Transport Agency's guide for concrete bridges taking into account the water/binder ratio, air content and the binder composition of the concrete. The concrete mixes were pre-tested for freeze-thaw with de-icing salt resistance.





Title	<b>Water treatment plant, Valenton</b>
Country	<b>France</b>
Type of structure	<b>Water treatment plant</b>
Cement type	<b>CEM V/A (S-V) 32,5 N</b>



As part of the extension of the Seine Amont water treatment plant, approximately 50 000 tonnes of CEM V/A (S-V) 32,5 N were used to build the 12 basins, which are more than 10 metres deep. This extension has doubled the treatment capacity to 600 000 m<sup>3</sup> per day. Due to the technical characteristics of the cement, the concrete has a guaranteed strength of 40 MPa at 28 days. The use of this cement not only ensured the mechanical requirements were met, but also enhanced the structure's resistance to chemical attack.

Title	<b>Larrelter Polder wind farm: towers for wind turbines</b>
Country	<b>Germany</b>
Type of structure	<b>Wind turbine towers</b>
Cement type	<b>CEM III/A 42,5 N</b>



With a nominal power of 6 megawatts, these turbines are among the most powerful in the world and both the towers and their foundations are made of concrete. The towers are 124 metres high and, when taking into consideration the wind turbines, the total height of the structure is more than 180 metres. The rotary blades are 114 metres in diameter. The structures were built on site, using ready-mixed concrete prepared with blastfurnace cement CEM III/A 42,5 N. Around 2 000 m<sup>3</sup> of concrete (class C30/37 - C35/45) were used for each tower of which half was class C35/45. For the foundations, 1 000 m<sup>3</sup> of concrete (class C30/37 and C35/45) were used. The choice of CEM III/A was driven by environmental and technical issues. Its high slag content allows significant reduction of CO<sub>2</sub> emissions during its production. From a technical point of view, it allowed for the production of a concrete which is workable for long periods of time, even in summer conditions.



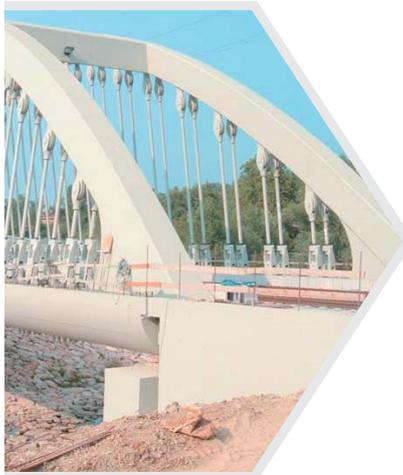


Title	<b>Kilronan Harbour Development, Aran Islands, Galway</b>
Country	<b>Ireland</b>
Type of structure	<b>Harbour Redevelopment – breakwater, pier, cargo quay, slipways, deep-water berths, floating pontoon and associated services</b>
Cement type	<b>CEM II/A-L</b>



The Aran Islands are located 15 km off Galway on Ireland’s west coast. The goal of the project was to provide a safe harbour with improved berthing facilities for fishing, commercial and tourist traffic and faster launch times for the RNLi lifeboat. The outcomes of the various investigations produced the optimum design for the harbour while ensuring that it provided adequate protection during Atlantic storms. All of the concrete for the project was produced on the island using a 120-tonne single-silo batching plant. A variety of concrete mixes were produced, with concrete strength classes ranging from C30/37 to C40/50. Underwater concrete was also an important feature of the project. The marine environment demanded concrete that would withstand exposure to chlorides resulting in XS3 exposure class being specified for much of the concrete. CEM II/A-L cement was selected because of product quality and consistency and its versatility for use in a range of concrete applications. Security of supply and logistics were also important factors. Bulk cement tankers were shipped from the mainland by landing craft. Sand and aggregates were sourced locally on the island. Precast concrete units placed on mass concrete foundations cast onto rock were used for other parts of the project. Choosing CEM II/A-L permitted the use of a single-silo batching plant to fulfil all concrete requirements.

Title	<b>Italian High Speed Network – Florence/Bologna railway stretch</b>
Country	<b>Italy</b>
Type of structure	<b>Railway</b>
Cement type	<b>CEM I, CEM II/A, CEM IV/A, CEM IV/B</b>



Over the last fifteen years, the new Italian high-speed network, built in order to increase the capacity of the currently operating railway lines, nearly doubling the actual number of trains running daily, and decreasing travelling time, has required a huge financial investment, involved large engineering resources, construction skills and strict planning, managing and organisation, and supervision of railway engineers. The new lines have been designed according to the national code for the design and construction of railway bridges, and meet the most advanced technological standards in order to achieve the best conditions in terms of service, speed and interoperability between national railways and European high-speed railway lines. More than 90% of bridges and viaducts which make up the new high-speed lines have been constructed using simply-supported spans of pre-stressed concrete (PC) decks. The rest is made up of simply-supported composite steel and concrete spans, a few continuous bridges and some special structures (arch bridges and the cable-stayed bridge over the river Po).

The main types of cement used were:

- Tunnel - Coatings of inverted arches and barriers: CEM IV/B 32,5 R; IV/A 32,5 R; IV/A 42,5 R; IV/B 42,5 R
- Tunnel - Coatings of calottes and jambs: CEM IV/B 32,5 R; IV/A32,5 R; IV/A 42,5 R; IV/B 42,5 R; IV/B-P 32,5R
- Outside - Supporting walls, foundation, concrete for buildings, box-type structures (<8 m span), piles, bulkheads: CEM IV/B 32,5 R; IV/A 32,5 R; IV/A 42,5 R; IV/B 42,5



- Viaducts - Piers, abutments, slabs for decks, box-type structures (> 8 m span): CEM IV/B 32,5 R; IV/A32,5 R; IV/A 42,5 R; IV/B 42,5 R; IV/B-P 32,5 R; II/A-LL 42,5 R
- Pre-stressed structures: CEM IV/A 42,5 R; IV/B 42,5 R; I 52,5 R; II/A-LL 42,5 R AARS (Very High Sulphate Resistance according to the Italian standard UNI 9156)



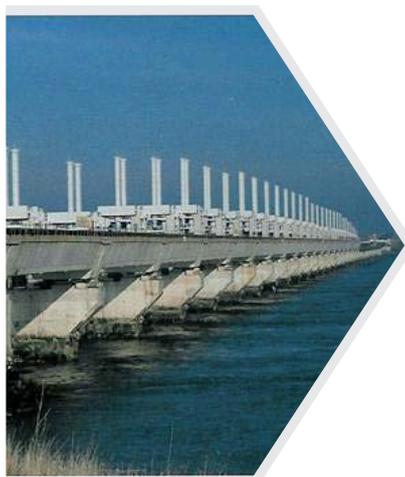
These kinds of cements (mainly CEM IV/A and IV/B) were chosen because they allow for the development of structures characterised by high chemical resistance and high durability.

Title	<b>The water tower in Leudelange – the elegance of the square</b>
Country	<b>Luxembourg</b>
Type of structure	<b>Water tower</b>
Cement type	<b>CEM III/B 32,5 N – LH</b>



This prestigious, elegant and impressive building features 58 metres of architectural concrete and took three years to build using advanced construction methods. Built to meet the needs of a growing population and an area in continuous development, the water tower of Leudelange features two water tanks built on different levels to reduce the pressure differential. 4 500 m<sup>3</sup> of architectural concrete were used to build the water tower. The concrete is composed of light-coloured aggregates and blastfurnace cement to obtain the desired grey/white shade and was cast in slightly absorbent forms to obtain a smooth surface upon removal. A climbing formwork was used to create the load-bearing pillars for the upper water tank. It was decided to construct the building using high quality reinforced concrete cast on site. Concrete C30/37 made with blastfurnace cement CEM III/B 32,5 N – LH was used. The large amount of slag in the cement resulted in a concrete with a light grey colour and reduced heat of hydration, which was particularly relevant to reduce thermal cracks in the very thick structural elements.

Title	<b>Eastern Scheldt Barrier</b>
Country	<b>The Netherlands</b>
Type of structure	<b>Storm surge barrier</b>
Cement type	<b>CEM III/B</b>



For the Eastern Scheldt Barrier, which was designed and built in the early eighties, the durability requirements were, for the first time, expressed in terms of time: a service life of 200 years. As this was not feasible for the concrete cover, a mean service life of around 85 years was accepted. Future maintenance was also considered during the design stages. The 2 800 m-long storm surge barrier across the Eastern Scheldt is very impressive. In order to affect the natural tidal range as little as possible the barrier contains 62 openings that can be closed using steel sliding doors when there is an increased risk of flooding. During normal weather conditions the sliding doors are fixed in a raised position. The complete barrier comprises 65 monolithic piers. The concrete piers are considered to be the backbone of the storm surge barrier, transferring the forces exerted by a storm to the foundation. Each pier was cast in several phases. The concrete composition of each phase contained 350 kg per cubic metre CEM III/B and the target water-cement ratio was 0,45. The concrete was actively cooled with cooling tubes to avoid thermal cracks.





Title	<b>Millennium Bridge</b>
Country	<b>Poland</b>
Type of structure	<b>Cable-stayed bridge (cantilever concreting)</b>
Cement type	<b>CEM II/BS 42,5 N – pylons, CEM III/A 32,5 N – foundations and pile foundation</b>



The Millennium Bridge in Wrocław forms part of the Central Ring Road, the aim of which is to relieve the city centre of heavy transit traffic. Up until now, only the western part of the ring road had been constructed. The Millennium Bridge is 972 m long and 25 m wide. The bridge will have two carriageways with two traffic lanes (each one will be 2 x 3.5 m wide), walkways and bicycle tracks on both sides of the bridge (3.5 m wide). Regarding construction, the bridge is composed of three structures: a 7-span flyover on the left river bank, a suspension bridge over the main stream of the Oder river and the right-bank bridge over the barge winter port with 2-span right-bank flyover. The cable-stayed bridge is suspended on 56 cables held by two towers in an H structure, 50 m high. The span lengths are 68.5 m + 153 m + 68.5 m. The main structural system is composed of two main girders and cross beams spaced every 10.55 m which, behind the girders, form anchor blocks for cables. In effect, the cables are led beyond the bridge deck. The cable-stayed bridge, the first structure of this type in Poland, was constructed with the use of cantilever concreting.

Title	<b>Edifício Vodafone (Oporto Vodafone Building)</b>
Country	<b>Portugal</b>
Type of structure	<b>Office Building</b>
Cement type	<b>White Cement - CEM II/A-L 52,5 N</b>



The Vodafone headquarters in the city of Oporto is a major white concrete building dating from 2009. The building, which will accommodate all of the company's departments, has eight floors, five of which are above ground and three underground, with a total area of 4 700 m<sup>2</sup>. Developed by architects António Barbosa and Pedro Guimarães, its modern design aimed to create a sense of movement and dynamism, in line with the Vodafone image, through the angular windows of its façades. According to the architects, "the development of this concept is based on concrete, which through its plasticity, allows for the creation of irregular and free-form shapes, working both as a structural solution and providing an exterior appearance, creating a unique shape, a monolithic building, bringing cohesion and unity". From an engineering point of view, the construction proved to be a challenge because "the technical complexity of the building leads to a peripheral structural solution, a concrete shell, like an egg, reducing internal support to two stairwells and three central pillars, allowing for great versatility when using its interior space" (Guimarães). A natural scale prototype was built to test the specificities of the CEM II/A-L 52,5 N white cement concrete panel - colour, texture, plasticity, formwork panel design and also curing period. Reinforced concrete was used for the upper level slabs. However, for the northern and southern panels, engineers chose a self-compacting, cast-in-situ concrete structure. The Vodafone headquarters took two years to build, with an overall cost of €13.4 million, and was made entirely with lower clinker cement.



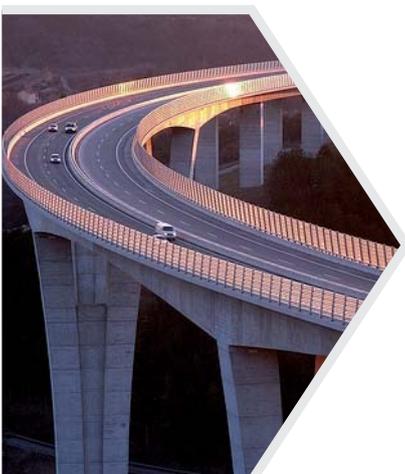


Title	<b>Palace of the Parliament</b>
Country	<b>Romania</b>
Type of structure	<b>Government building</b>
Cement type	<b>CEM II/A-S 32,5 R and CEM II/A-S 32,5 N LH</b>



Portland-slag (CEM II/A-S) cements were used in the construction of the world's largest civilian administrative building. The Palace of the Parliament in Bucharest is a multi-purpose marble building containing both chambers of the Romanian Parliament. The Palace measures 270 m by 240 m, 86 m high, and 92 m underground. It has 1 100 rooms, two underground parking garages and is 12 stories tall, with four additional underground levels currently available for the general public, and another four in different stages of completion. Construction began in 1983. Concrete foundations using CEM II cement support the huge weight of the marble building. Most of the cement used for the structure was a CEM II/A-S 32,5 R. For massive foundations and other massive elements, a Hz 35 cement (corresponding to CEM II/A-S 32,5 N-LH) was used. P 40 and P 45 cements (corresponding to CEM I 42,5 R) were used only for a small amount of elements, most of them prefabricated.

Title	<b>Črni Kal</b>
Country	<b>Slovenia</b>
Type of structure	<b>Viaduct</b>
Cement type	<b>CEM V/A (S-P) 32,5 N LH, CEM II/A-S 42,5 R</b>



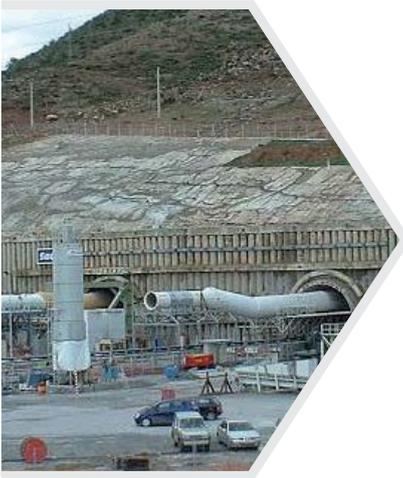
The Črni Kal Viaduct is the longest and the highest viaduct in Slovenia. It is located on the A1 Maribor–Ljubljana–Koper motorway above the Osp Valley near the village of Gabrovica, about 20 km east of Koper. Construction work began in 2001 and the viaduct was opened for traffic in 2004. Daily traffic comes to about 20 000 vehicles. The viaduct's supporting structure consists of two end pillars and eleven columns, five of which are twin low pillars spanning from 10 to 27 metres high; the remaining six high single pillars in the upper split are in the form of the letter "Y". The maximum height of the pillar is 87.5 m, including the construction of the carriageway which measures 95 metres. The maximum span between pillars is 140 metres. The total width of the viaduct is 26.5 m; the pavement structures are separated from each other.

About 50 000 cubic metres of concrete, using lower-clinker cements exclusively, were used. For the foundations of the pillars, CEM V cement, with a low heat of hydration, was used and concrete for almost all other construction works was produced with CEM II. CEM II was also applied for the self-compacting concrete (SCC).



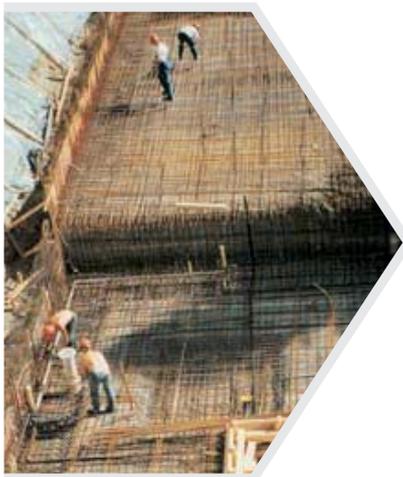


Title	<b>High speed Córdoba-Málaga line</b>
Country	<b>Spain</b>
Type of structure	<b>Railway</b>
Cement type	<b>CEM II/A-S 42,5 N</b>



The new high-speed railway line between Córdoba and Málaga is made up of 22 sections and is 155 km long. Thanks to 19 km of tunnels, the railway system travels through the Baetic Cordillera mountain range. The Abdalajís tunnel alone is more than 7 km long. Work began in November 2003 and took 26 months to complete. CEM II/A-S 42,5 N was used to obtain the backfilling mortar which fully satisfied the mechanical requirements, durability and low permeability required by the site. In addition, it provided greater resistance to sulfates and chemical attack. This resistance prevented soil sulfates from entering the concrete. This cement type is also eco-efficient. It reflects the cement industry's commitment to minimising resource use and producing less waste and emissions per tonne of cement. This cement significantly reduces the CO<sub>2</sub> emitted in cement manufacture thanks to the use of alternative raw materials, alternative fuels and additions that also improve the cement's properties.

Title	<b>Reservoir for drinking water</b>
Country	<b>Switzerland</b>
Type of structure	<b>Water reservoir</b>
Cement type	<b>CEM III/B 32,5 N HS LH</b>



The Clùx water reservoir plays a central role in the water supply for the community of Pontresina. For the construction of this reservoir a watertight concrete was required. To ensure the quality of the water, plastic or mineral coats could not be used to render the required low permeability. To achieve the needed quality, blastfurnace cement was used. The reasons for this choice were the lower heat of hydration of the cement, which helped to avoid thermal cracks, its denser microstructure and its resistance to chemical attack promoted by soft water.





Title	<b>Enova Berkman Hydroelectricity Plant - Kumarlı - OSMANİYE</b>
Country	<b>Turkey</b>
Type of structure	<b>Hydroelectricity Plant</b>
Cement type	<b>CEM II/B-S 42,5 R, CEM II/B-M 42,5 N, CEM III/A 42,5 N</b>



The Oşkan & Berkman Hydroelectricity Plants have been built on the River Ceyhan, in the city of Osmaniye, with the aim of producing 250 million kWh of energy per year. CEM III/A and CEM II/B-S cements were used in the project in 450 000 m<sup>3</sup> of C14-C20-C25-C30 Self-Consolidating Injection Concrete. Slag cement has the advantage of a low heat of hydration thus decreasing the risk of cracking in the concrete mass. Crack-proof concrete increases the durability and service-life of the concrete used in the hydroelectricity plant. Slag cement also improves the sulfate resistance of concrete, which is another important aspect of concrete in aqueous structures. Supplementary advantages, such as the high compressive strength and low permeability of slag cement, result in a model concrete for other hydroelectricity plants being constructed in the region.

Title	<b>Spinnaker Tower, Gunwharf Quays, Portsmouth</b>
Country	<b>United Kingdom</b>
Type of structure	<b>Millennium monument</b>
Cement type	<b>CEM I combined with ggbs</b>



A CEM I cement, combined with a high proportion of blastfurnace slag (ggbs) in the concrete mixer, was specified for the 170 m Spinnaker Tower in Portsmouth's Gunwharf Quays development, where its use gives the concrete a distinct lighter colour. In addition, the slower setting cement helped ensure that the workability properties of the fresh concrete remained consistent during the extended slip-form placing of 11 000 m<sup>3</sup> during construction over three months.



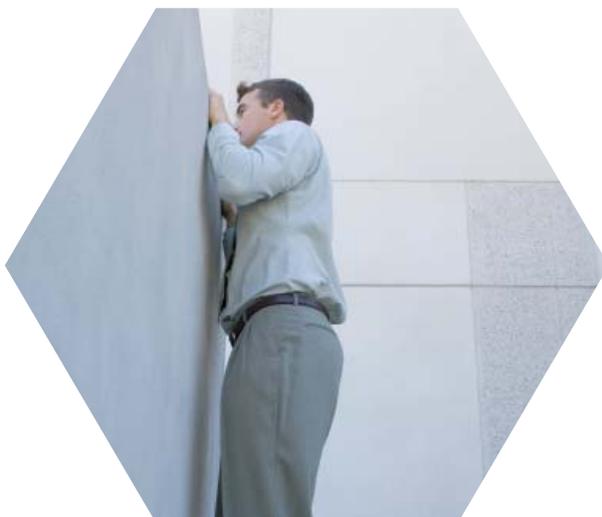
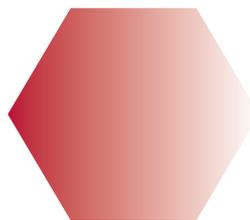
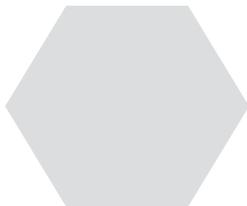
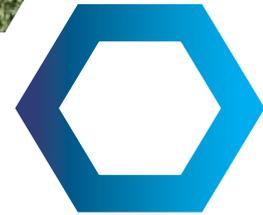
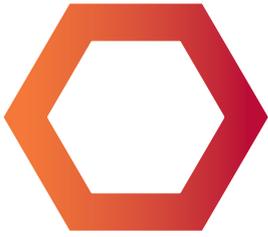


## FURTHER INFORMATION

More detailed information on developments in the European cement industry can be found in the following publications:

- Cement Technology Roadmap: Carbon emissions reductions up to 2050 (IEA/CSI, 2009 [http://www.iea.org/papers/2009/Cement\\_Roadmap.pdf](http://www.iea.org/papers/2009/Cement_Roadmap.pdf))
- Development of State of the Art Techniques in Cement Manufacture: Trying to Look Ahead (ECRA/CSI, 2009 <http://www.wbcdcement.org/pdf/technology/Technology%20papers.pdf>)
- Sustainable Cement Production: Co-processing of Alternative Fuels and Raw Materials in the Cement Industry (CEMBUREAU, 2009 <http://www.cembureau.eu/sustainable-cement-production-co-processing-alternative-fuels-and-raw-materials-cement-industry>)
- Building a Future with Cement and Concrete: Adapting to Climate Change by Planning Sustainable Construction (CEMBUREAU, 2009 <http://www.cembureau.eu/building-future-cement-concrete-adapting-climate-change-planning-sustainable-construction>)
- Concrete for Energy Efficient Buildings. The Benefits of Thermal mass (ECP, 2007 [http://www.europeanconcrete.eu/images/stories/publications/en\\_energy\\_performance\\_brochure.pdf?phpMyAdmin=16bbb563ca43adfed14bd78eb7d8cd8a](http://www.europeanconcrete.eu/images/stories/publications/en_energy_performance_brochure.pdf?phpMyAdmin=16bbb563ca43adfed14bd78eb7d8cd8a))
- European Cement Research Academy. CCS - Carbon Capture and Storage (<http://www.ecra-online.org/226/>)





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