Chapter 2
Concrete Industry: Waste Generation and Environmental Concerns

In the second half of the last century, the world production of goods and services increased disproportionately, due to a strong demographic growth, expansion of urban areas and a great development of industrialization. Apart from undoubted benefits in terms of improved living standards, this phenomenon also resulted in an growing pressure on natural balances and resources of the Earth. However, the above mentioned process led to a remarkable increase in waste generation.

The origin of waste is manifold and there is no uniform and generally accepted classification across all countries. Nevertheless, the following classification is often adopted (Chalmin and Gaillochet 2009):

- municipal waste, produced by individuals and economic activities;
- industrial waste, related to production processes;
- construction and demolition waste and waste from mining operations.

Moreover, regardless the previous classification, waste can also be defined as hazardous or non-hazardous, depending on their chemical composition and treatments for their disposal (AITEC 2011).

Making a credible appraisal of the total waste production in the world is not an easy task, because of both the absence of reliable data in developing countries and the different waste classifications existing worldwide. However, according to recent researches (Chalmin and Gaillochet 2009), about four billions of tons of solid industrial and municipal waste are produced worldwide every year. Slightly more than one half of such waste is collected and recycled: this is municipal waste (1.7 billion), including domestic and commercial ones, but also industrial waste, especially in manufacture industry (EEA 2007).

Even though the recent global recession significantly affected the economy of Western countries leading to a drop in production, the significant growth of emerging countries, such as Brazil, Russia, China and India, kept the global demand for goods and services on an increasing trend. Thus, adopting a policy for a sustainable development at the global scale is more and more necessary, in order to satisfy the socio-economic needs and safeguard the environmental resources at the same time.

In Europe, the contribution of each industrial sector to the generation of waste is well described by EEA (European Environment Agency), considering data from the first 15 Member States of the European Union. The percentages of waste production

M. Pepe, *A Conceptual Model for Designing Recycled Aggregate Concrete for Structural Applications*, Springer Theses,
DOI 10.1007/978-3-319-26473-8_2

vary considerably among different sectors and waste categories, reflecting different socio-economic factors. It is interesting to note that the largest percentage (48 %) corresponds to construction and demolition waste (C&D), whereas municipal waste, which probably better represents the idea of waste in the common way of thinking, is only about 12 % (Fig. 2.1).

Another remarkable consequence of industrialization and growth of production of goods and services is certainly the emission of carbon dioxide (CO_2) in the atmosphere. Since the XIX century, it was found that CO_2 emissions affect Earth's temperature through the so-called "global warming" or "greenhouse effect" (IEA 2011). However, only in the '90s of the past century, a wide scientific debate was initiated for investigating the actual relationship between the so-called "greenhouse gas" emissions and the "global warming" effect.

Due to the growth of industrial activities in countries such as China, India, Russia and Brazil, which added to the steady industrial potential of Western Europe, Japan and United States, global warming has achieved warning levels (Fig. 2.2). Therefore,

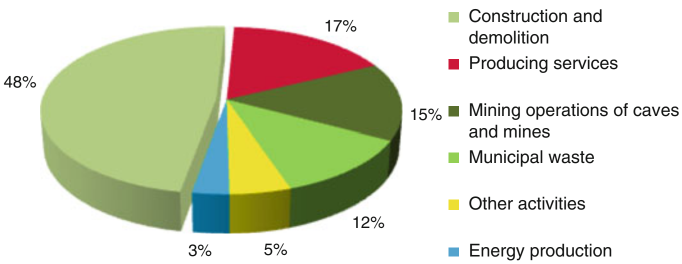
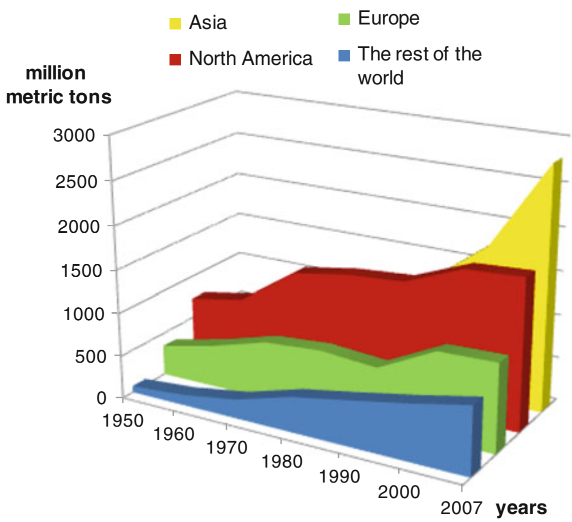


Fig. 2.1 Total waste generation per sector in UE 15 (EEA 2007)

Fig. 2.2 Total carbon emissions in the world since 1950 (Washington Post 2009)



in 1997, 160 countries signed the "Kyoto Protocol", an international treaty which commits industrialised countries in the period 2008–2012 to reduce greenhouse gas emissions not less than 5 % compared to the emissions recorded in 1990, regarded as the base year. Particularly, the following compounds were considered as greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF_6).

However, United States backed off in 2001 after having ratified the protocol, while India, China and other developing countries were initially exempted from implementing the "Kyoto Protocol" because they were not among the major responsible of global emissions during in the last decades, when climate change become a major issue.

According to the most recent evaluations made by IEA (International Energy Agency), global greenhouse gas emissions achieved 30.6 billion tons in 2010. Since the time-line of the "Kyoto Protocol" was limited to 2012, the "2011 United Nations Climate Change Conference" was held in Durban (ZA) from 28 November to 11 December 2011, in order to establish a new treaty about carbon emissions limits. The conference agreed to a legally binding deal committing all countries, which will be prepared by 2015 and taking effect in 2020. The agreement, referred to as the "Durban platform", was notable in that for the first time it included developing countries, such as China and India, as well as the United States which refused to accept the Kyoto Protocol.

Apart from water vapour, which is not related to industrialisation or human activities, carbon dioxide (CO_2) is generally considered as the major responsible for greenhouse effect. Thus, it is useful to investigate how specific productive sectors contribute to its emission. Figure 2.3 shows that the cement industry contributes 5 % of the global CO_2 emissions and, then, it is one of the most impacting sectors to be duly considered in any "green strategies". Think for example of non-road transportation, which also produce the 5 % of the total carbon dioxide emissions. Boeing, Airbus and Embraer, three world leaders in aviation industry, signed in March 2012 an agreement in order to produce bio-fuels and to halve the emissions by 2050, compared to the levels recorded in 2005 (http://www.boeingitaly.it, 2012).

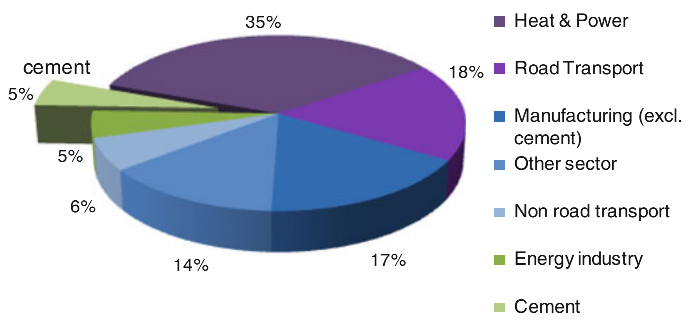


Fig. 2.3 Global CO_2 production worldwide (WBCSD 2012)

Consequently, a similar effort should be pursed to significantly reduce the environmental impact of concrete, with a particular emphasis on cement industry.

2.1 Construction and Demolition Waste

Construction and demolition waste are defined as all waste that arises from construction, renovation and demolition activities; furthermore in some countries even materials from land levelling are included.

According to the European List of Waste (EC 2000), C&D waste covers a very broad range of materials. Excluding non-hazardous waste, the most common categories identified are:

- concrete, bricks, tiles and ceramics;
- wood, glass and plastic;
- bituminous mixtures, coal tar and tarred products;
- metals;
- soil (including excavated soil from contaminated sites).

In Europe, about 850 million tons of these waste are generated every year, and this represents the 31 % of the total waste generation (Fig. 2.4). In recent years, several EU Member States have published results of analysis concerning the composition of C&D waste, and approximately one third of it consists of concrete (Böhmer et al. 2008).

In order to compare C&D waste production among European countries, it is useful to refer to values per capita. Thus, considering data between 2004 and 2006, Luxembourg has the highest production per capita, with 15 tonnes, while any other country does not exceed the half of this value (Fischer and Werge 2009). In 2004 France generated about 6 tons per capita, Finland 4 tons, while Germany showed a remarkable decrease of C&D waste production from 1995 to 2005, when <2 tons per capita were recorded. Finally, the large part of European countries, Italy included, generate between 1 and 2 tons.

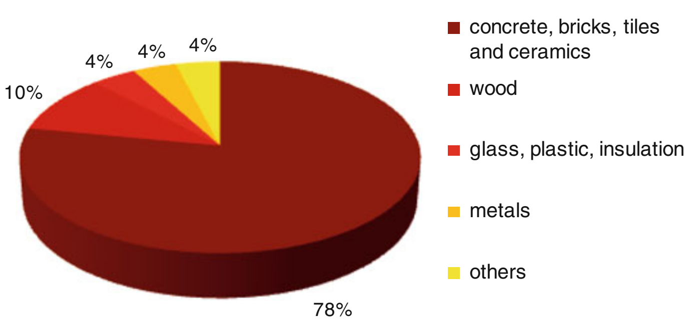


Fig. 2.4 C&D waste materials (Fischer and Werge 2009)

According to Italian regulation, construction and demolition waste are defined as "special waste", and need to undergo "special procedures about the collection, storage, transport and final disposal" (D.lgs. n° 156/2006 Art. 185). However in Italy, as well as in many countries of the European Union, especially the Netherlands and Denmark, morphological and environmental conditions suggest to avoid the opening of new landfills, and, then, enhance the production of recycled aggregates from C&D waste.

Taking this point into account, it is interesting to integrate the previous data about C&D waste production, in order to offer an overall view. In fact, even if Italy, Denmark, Netherland and Estonia generate almost the same amount of C&D waste per capita, Italy recycles only the 10 % of its production (Legambiente 2011), despite the remarkable results achieved by the other three mentioned countries, where the percentage of recycling is more than 90 %. However, other developed countries, such as France and Germany seem to have understood the necessity to avoid landfilling, as they have 60 and 86 %, respectively, of C&D waste recycling.

In recent years, both in order to limit the use of virgin materials in construction industry and to guarantee an environmental preservation, Europe adopted a policy to promote the reuse of recycled aggregate in concrete production. The European Directive n.98 of 19/11/2008 (EC 2008) calls on member states to take the necessary measures to promote the reuse of products and the preparing measures for re-use activities, particularly by promoting the establishment of economic tools and criteria about tenders, quantitative targets or other measures. Moreover, art. 11 specifies that the preparing for reuse, recycling and other types of recovery of material, including construction and demolition waste, shall be at least increased to 70 % (by weight) by 2020 (EDCW 2014).

2.2 Concrete and Construction Industry: Aggregates Sources

According to the European Aggregates Association, aggregates are granular material used in construction, and it is possible to identify three different categories:

- natural aggregates, produced from mineral sources, such as quarries and gravel pits, and in some countries from sea-dredged material;
- secondary aggregates, produced from industrial processes;
- recycled aggregates, produced from processing material previously used in construction.

In 2008, the German Umweltbundesamt (Böhmer et al. 2008) published a very accurate report about production and utilization of aggregates in Europe. Even if in some cases data are not available, such as for Denmark which surely adopts green policy, it is possible to note how the use of recycled aggregates is still far from being competitive as compared with natural aggregates (Figs. 2.5 and 2.6).

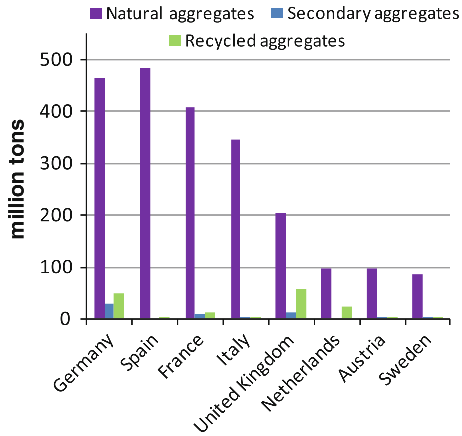


Fig. 2.5 Aggregates production in Europe (Böhmer et al. 2008)

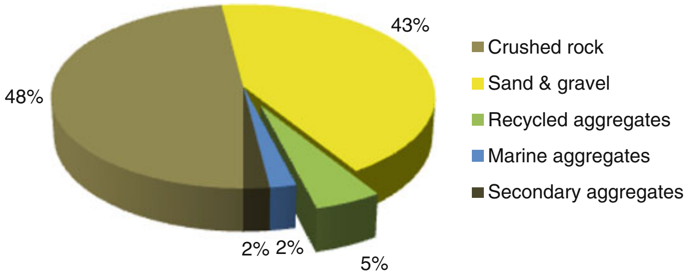


Fig. 2.6 Source of aggregates in Europe (Böhmer et al. 2008)

In Italy the exploitation of natural aggregates is well described by Legambiente (2011). The active quarries are 5736, distributed throughout the peninsula, with more than 500 quarries in Sicily, Veneto and Lombardia. However it is worth to highlight that about 180 unauthorised quarries have been estimated only in Campania. Moreover, there are almost 15000 abandoned quarries, concentrated in Lombardia, Veneto, Trentino, Toscana, Marche and Campania (Fig. 2.7).

Nevertheless, the most alarming aspect about natural aggregate management in Italy, is the regulatory framework, which is based upon a Royal Decree of 1927 (Legambiente 2011). In fact, only some regions adopted a "Quarries Plan" in order to regulate the exploitation of natural resources, but generally all regional laws are very far from a modern management which takes into account the landscape and the environment.

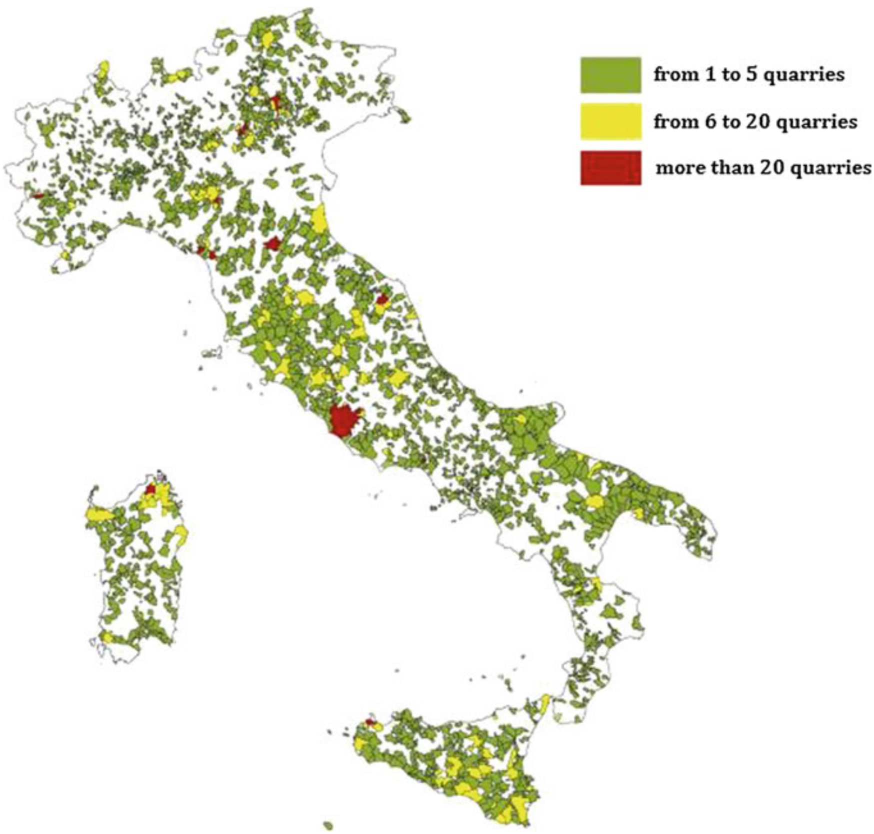


Fig. 2.7 Distribution of active quarries in Italy (Legambiente 2011)

2.3 Concrete and Construction Industry: Cement Production

In 2010 the world production of cement was 3.3 billion tons, with an increase of 7 % on the preceding year (USGS 2011). However, considering the infrastructure development in Asia and other emerging economies, such as Turkey and Brazil, cement production will further increase. China alone produces 1.8 billion tons of cement, which is 54 % of the world total, followed by India at 7 %, while the contribution of other major producers is no more than 2 % for each one (Table 2.1).

In Europe, Spain is the first cement producer, with 50 million tons, followed by Italy and Germany, with 35 and 31 million tons, respectively. However, it is quite interesting to note how Italy denotes the greatest cement production per km^2 among European countries (Fig. 2.8), and its production per capita is about 580 kg/inhabitant,

Table 2.1 First ten cement producer countries in the world (USGS 2011)

Country	Cement production (10^6 metric tons)
China	1800
India	220
United States	63.5
Turkey	60
Brazil	59
Japan	56
Iran	55
Spain	50
Vietnam	50
Russia	49

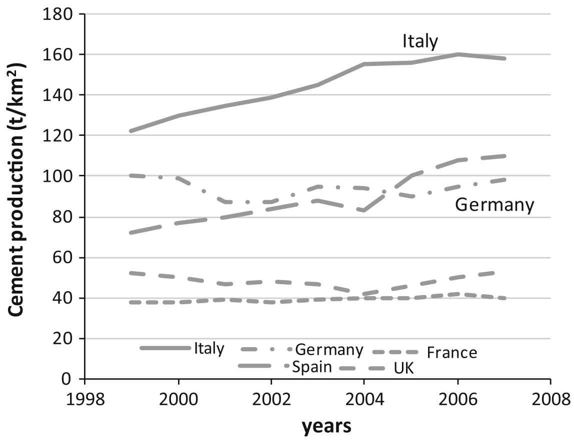


Fig. 2.8 Cement production per km^2 in Europe (AITEC 2011)

that is almost three times higher than India (187 kg/inhabitant) or the United States (206 kg/inhabitant).

As mentioned above, the cement industry produces about the 5 % of global carbon dioxide emissions. Figure 2.9 shows the unit-based CO_2 emissions due to cement production by country and region. Higher numerical values characterise the United States and the emerging Asian countries, while they are lower for countries, such as Japan, where energy efficient methods are widely adopted in the cement industry (ACF 2008).

The production of carbon dioxide from a cement plant derives from two main stages of the cement production, namely combustion and calcination. Combustion accounts for approximately 40 % and calcination for 50 %, whereas the remaining percentage is due to electricity and transport. The combustion-generated CO_2 emissions are related to fuel combustion, while CO_2 emissions due to calcination are formed when the raw materials (mostly limestone and clay) are heated to over 1500 °C.

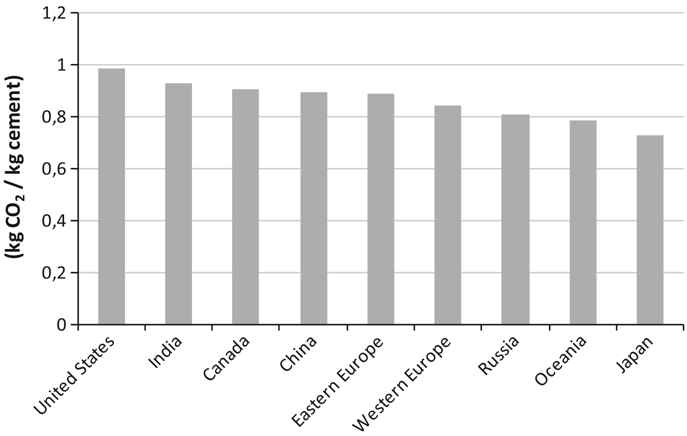


Fig. 2.9 Unit-based CO_2 emission due to cement production by country and region (ACF 2008)

According to a study realised by WWF and published in 2008, the world cement industry could reduce the emissions up to 90 % by 2050, considering technologies available nowadays about production techniques (Müller and Harnisch 2008). However, there is also a school of thought suggesting that it is essential to develop an innovative cement burning technology or move toward new types of cement (Sakai 2005).

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A Conceptual Model for Designing Recycled Aggregate Concrete for Structural Applications
Pepe, M.
2015, XVII, 167 p. 118 illus., 27 illus. in color.,
Hardcover
ISBN: 978-3-319-26472-1