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Quarrying activity and the building industry

Relations between the production of aggregates for the building industry and their demand for greater environmental sustainability.

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Abstract—Quarrying activity is a key-component of the GDP (gross domestic product) of industrialized economies, since various productive sectors depend on it. The mining industry also plays a strategic role as an employment source. In particular, the extraction of aggregates (sand, gravel and crushed stone), is closely related to the building sector. By analyzing the building activity and its trend in time, this research will highlight the relations between quarrying activity and the construction industry, and will focus on its ability to activate the demand for aggregates, that could lead to environmental risks.

Keywords-component; quarrying; aggregates; building industry; demand

I. INTRODUCTION

Quarrying activity plays a role of strategic importance in the global economy. By securing a supply of mineral raw materials, such activity promotes the development of industrialized countries. The most common uses of aggregates are closely related to the construction sector: e.g., they can be used either without a difficult manufacturing process, as in road filling, railway ballast or armor stones, or they can be used in high quality materials industrial production such as glass (quartz sands), ready-mixed concrete (made of 80% aggregates), pre-cast products, asphalt (made of 95% aggregates) [4], etc. Consequently, the resources of aggregates are used in the implementation of all built-up environments [3], in particular:

- Housing: the construction of a typical new home uses up to 308 cubic meters of aggregates.
- Civil Engineering (e.g. local hospitals, schools, bridges and flood protection, structures, etc.): the construction of a school uses up to 2,308 cubic meters of aggregates, while for a sports stadium, up to 230,770 cubic meters are needed
- Roads: the construction of 1 kilometer of motorway uses up to 23,077 cubic meters of aggregates.
- Railways: the construction of 1 meter of railway for a High Speed train (TGV) uses up to 7 cubic meters of aggregates.

In this context, the assessment of the demand for aggregates is extremely important, because a miscalculation could lead to market anomalies. In particular, overestimation would result in lower prices and environmental risks, while underestimation could lead to strong difficulties in the availability of aggregates.

II. SOME FACTS ABOUT THE EUROPEAN BUILDING INDUSTRY

Before analyzing the requirements of aggregates related to building activity, a brief preamble is necessary. It should be pointed out that the building industry is a particularly complex sector, since it is closely linked to a number of other sectors of the economic system. In the EU (European Union) the aggregates industry is the largest non-energy extractive sector with an output of 2.3 billion cubic meters produced every year and 400,000 employees, including sub-contractors [5]. With regard to the building industry, in 2009 it generated an economic value of € 1,173 billion in the 27 EU Members [6]. Despite the world economic crisis that began in 2008, some recent data, related to the construction sector in EU27 confirm its economic key-role: it provided 9.9% of GDP (gross domestic product) in 2009, and it is the biggest industrial employer in Europe, responsible for about 7.1% of Europe's total employment and 29.1% of industrial employment [6]. In particular, it has been estimated that 44.6 million workers in the EU depend, directly or indirectly, on the construction sector, with a significant effect: for each person working in the construction industry there are two further persons working in other sectors [7]. Fig. 1 shows the economic volume generated by EU building industry in 2009.

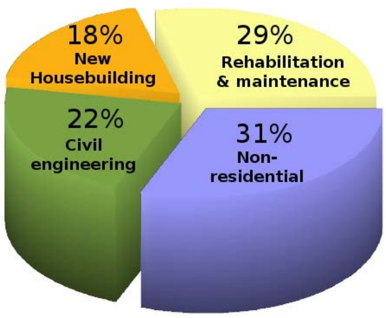

Figure 1. Construction in Europe - Main activities 2009 (source: FIEC, European Construction Industry Federation).

Certain activities, such as rehabilitation and maintenance, are frequently left out in the assessment of the demand for aggregates. This approach risks underestimating the real need for aggregates: in fact, Fig. 1 shows that rehabilitation and maintenance amount to 29% of the total economic volume produced by the EU building industry, the second in importance. During the period 1990–2009 the development of the EU construction industry tended to follow cyclic trends [3]: 1993–1999 (first cycle), 1999–2006 (second cycle). According to past cycles, a third cycle from 2007 to 2012 was expected, with a growth rate increasing in the 2008-2009 period, and the next peak in 2012. However, the widespread economic crisis has resulted in a slowdown of the construction industry growth and in a sharp decline in the construction market activity in a number of European countries [4]. According to such data, after the 2006 peak, with a production of 2.85 billion cubic meters, the production of aggregates decreased to around 2.7 billion cubic meters in 2008, as a consequence of the economic crisis and a further decrease to around 2.2 cubic meters in 2009 [5] is predicted to occur. Although the current growth rates are lower than the expectations, the prospects for 2010 tend towards stability, and a modest growth is expected to return in 2011. In fact, in spite of further reduction in private building demand, various European countries have chosen to develop civil engineering works. For instance, in Spain, after a strong reduction in private building demand (-21.7% residential buildings and -13.5% non-residential buildings), the Government decided to raise investment in civil engineering works (+2.5%). Similar approaches were pursued in Portugal (+5.0%), Austria (+1.5%) and Sweden (+9.4%) [13]. Therefore, the consumption of aggregates is expected to increase as a result of a mild recovery of the civil engineering sector of the EU building industry.

Moreover, since the consumption of aggregates is closely related to the economic performance of a country, which is measured as gross domestic product per capita (GDP/capita), if we assume that some of the new emerging EU Member States will soon reach a GDP/capita of €25,000, in the near future this will result in an increase in the consumption of aggregates, estimated at more than 3 billion cubic meters of aggregates [5].

III. The Italian Case Study

A. *Recent developments of the Building Industry in Italy*

According to a study performed in 2001 by ANCE (the National Association of Builders) [12], the Italian building and construction industry is closely related to 73 of the 92 productive sectors of the Italian economy. An increase of 5.16 billion euros in the final demand for buildings can activate domestic production by 9.28 billion euros, as shown in Table I. Moreover, a potential increase in production of 5.16 billion euros can create 122,000 new jobs. Some recent analyses [13] show that in 2009 there were 1,944,000 persons engaged in the Italian building and construction industry, corresponding to 28.9% of the total number of industrial employees and to 8.4% of the total number of employees of the entire Italian economic system (Fig. 2).

TABLE I. Direct And Indirect Effects On Production Activated By An Extra Demand Of 5.16 Billion Euros In The Building Sector

Activity	Output	
	Million EUR	***% of the total***
Building enterprises	5,164.57	56
Main productive branches of supply:	4,112.03	44
Lime, cement, plaster and products thereof	464.81	5
Ceramic and terra-cotta products	209.68	2
Building elements, reservoirs, boilers	220.01	2
Mineral extraction	86.25	1
Other branches	3,131.28	34
TOTAL	9,276.60	100

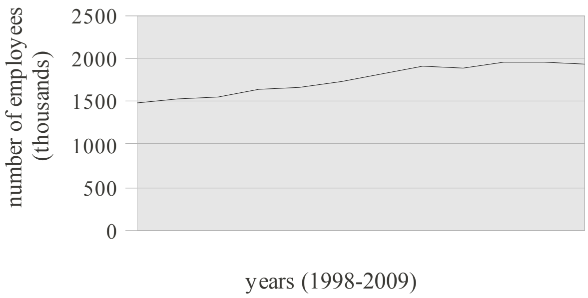

Figure 2. Persons engaged in the Italian building and construction industry for the period 1998-2009 (source: ANCE).

In Italy the private building market tends to follow ten-year cycles, and the state of the property market is inversely proportional to that of the financial markets. The last peak occurred in 2008, when the private building market, after 12 years of growth, performed a turnaround due to the world economic crisis stemming from the United States. As a consequence, all the Italian sectors related to the building industry except for building renovation have been subject to decline. Such sectors, together with housing redevelopment, tend towards stability, and the cause is the Government's decision to stimulate building renovation by providing tax breaks. As a result, during the first months of 2010 recession relief in the building industry is expected, while mild growth of +1% [13] in the building renovation sector is estimated.

B. *Relations between the production of aggregates and the shape of the city: case studies*

The demand for aggregates usually comes from the following building forms: residential and productive buildings. In this research only private demand will be taken into account. The need for houses is not and cannot be deduced only from the number of resident inhabitants, but also from migratory trends and from the changing requirements of the population induced by structural changes, such as either an increase in the average life span, or a decrease in the number of inhabitants of young age groups that lead to new and different ways of life. Among the Italian regions that have tried to face the issue and have produced a specific body of legislation, we quote Lombardy, which specifically by means of a law passed in 1998 (New provisions governing the mining of quarry minerals) introduced variables to be taken into consideration in evaluating the requirements for aggregates in the province, and established yearly regional average requirements of gravels and sands of 4 cubic meters per inhabitant. We believe, however, that this figure is excessive; in fact, as will be seen later in this work, the main reasons depend on the shape of the city.

The relationship between the consumption of minerals for private buildings and the shape of the city and the implications thereof deserve further attention, especially from a town-planning point of view. The literature is particularly rich on this subject, but for simplicity we shall distinguish between the two main urban shapes, the “compact city” and the “spread out city”. The “spread out” city is the urban model that originated in the United States between the late fifties and the sixties in contrast with the “compact city”. A characteristic of the "spread out city" is the low cost of its supply of dwellings and the progressive increase in individual mobility. In Italy the "spread out" city developed later than the American model, and was the combined result of two main factors: the proliferation of areas of residential expansion at the margins of the city, and a concomitant analogous increase in individual mobility. The compact city has a greater dwelling density, which is expressed by an increase in high rise buildings and a contraction of private spaces. Overestimation of the demand for aggregates means that greater amounts are extracted than required by the market, which leads to price reductions, unsold supplies and also stimulates exportation. Having said this, we can now account for the fact that a number of elements contribute to defining the shape of a city, which in turn, defines a number of different quantities of aggregates both for the construction of new buildings and for the reconversion of existing ones.

Figure 3. Geographic location of the case studies.

In particular, in the Province of Milan, the annual per capita aggregates used only for building purposes is about 1 cubic meter per inhabitant. Milan has grown very fast in demographic terms: while the latest 2001 census [14] showed in the Province of Milan a density of just above 1900 inhabitants per square kilometer, some recent data from 2009 [15] show a density of 1983 inhabitants per square kilometer. By comparing the city of Milan with another city in Lombardy, Mantua, it has been possible to show the relationship between city shape and requirements of minerals for building activity. Due to the urban shape of Milan, a "compact city" shape, in such Provinces the consumption of aggregates is 1.07 cubic meters per capita [21], while in the Province of Mantua (density of 176 inhabitants per square kilometer [15]), the consumption is 1.24 cubic meters per capita [22]. There are similar relationships at the national level, in particular if we try to compare the average per capita consumption on the main Italian islands (Sicily and Sardinia). Such islands must refer exclusively to their own environmental resources because of the modest market value of the extracted materials. In fact these island Regions cannot import minerals for building activity because of the high transport costs; nevertheless they are clearly characterized by their particular dwelling models. Table II shows the average per capita consumption of aggregates in each Italian Region, based on 2003 data [18][19], related to building production and population density. Sicily and Sardinia are geographically similar, but have different dwelling models. The use of aggregates per resident inhabitant shows that consumption in Sicily is lower than in Sardinia and the same happens for the production of buildings per inhabitant, which shows better conditions in Sicily compared to Sardinia. We are dealing here with two analogous geographic conditions of insularity, but with different forms of urban settlement: in fact, the population density in Sicily is higher than in Sardinia (195 vs 68 inhabitants per square kilometer), a fact that suggests a more compact urban settlement. As noted above, the total number of inhabitants is not the best indicator to express the relationship between building requirements and consequent environmental extraction. In fact, although Sicily is more densely populated than Sardinia (5,003,262 inhabitants vs 1,643,096 in 2003), this fact is not significant as regards the extraction of aggregates (0.92 cubic meters per capita vs 7.37). Building modalities are another important factor. In particular, the passage from load-bearing masonry to structures with a concrete load-bearing skeleton deserves particular attention. In this sense we are assisted by the Campania Regional Mining Plan (2003) [20], which identifies a significant methodology to define the amount of minerals related to the different building types, drawing a distinction between residential and non-residential buildings (only private). From the results it can be observed that the prevalence of “in situ concrete” bearing structures amounts to about 86% for residential buildings compared to 44% for non-residential buildings. However, experience has shown that these materials also represent most of those used in reconversion and restoration works. Analyzing the history of building production in Italy, the fifties and sixties appear to be crucial years.

	Residential buildings		Non-residential buildings						
Regions	***New Building Production (cubic meters)***	***Extensions (cubic meters)***	***New Building Production (cubic meters)***	***Extensions (cubic meters)***	***Popula-tion density***	***Total (cubic meters v.p.p.)***	***Per capita built-up (cubic meters)***	***Production of aggregates (cubic meters)[a]***	***Per capita production of aggregates (cubic meters)***
Piedmont	6,496,545	10,445,451	751,925	2,170,072	168	19,863,993	4.65	18,281,538	4.28
Valle d'Aosta	199,557	80,290	21,478	21,992	37	323,317	2.65	316,154	2.59
Lombardy	20,552,302	24,310,434	2,146,162	5,996,088	387	53,004,986	5.73	29,763,077	3.22
Trentino-Alto Adige	2,713,767	4,052,485	396,766	1,579,507	71	8,742,525	9.08	4,162,308	4.32
Veneto	13,865,111	19,127,311	1,841,589	5,254,274	252	40,088,285	8.63	23,604,615	5.08
Friuli-Venezia Giulia	2,911,086	3,809,054	267,016	1,083,824	152	8,070,980	6.74	2,637,692	2.20
Liguria	886,683	1,857,414	232,452	112,905	291	3,089,454	1.96	1,846,151	1.17
Emilia-Romagna	10,936,325	14,377,697	832,351	5,092,187	184	31,238,560	7.66	25,285,385	6.20
Tuscany	4,785,326	6,491,025	356,062	1,271,779	155	12,904,192	3.62	5,566,154	1.56
Umbria	1,480,415	1,530,971	142,092	595,414	100	3,748,892	4.42	4,950,769	5.84
Marche	3,436,779	5,216,447	243,142	1,115,929	155	10,012,297	6.65	5,573,876	3.70
Latium	6,225,634	5,832,470	265,952	629,974	302	12,954,030	2.49	23,747,692	4.56
Abruzzo	3,066,526	2,950,018	236,179	759,330	119	7,012,053	5.45	6,000,000	4.67
Molise	600,300	776,016	50,610	89,342	72	1,516,268	4.71	2,256,923	7.02
Campania	4,938,277	8,781,173	687,299	1,504,975	424	15,911,724	2.76	1,185,385	0.21
Puglia	5,976,168	6,021,062	682,295	1,362,018	209	14,041,543	3.47	32,143,846	7.95
Basilicata	710,540	1,721,950	68,167	169,023	60	2,669,680	4.47	842,308	1.41
Calabria	3,048,108	4,706,820	317,419	419,792	133	8,492,139	4.22	1,615,385	0.80
Sicily	5,924,138	6,457,628	559,879	828,629	**195**	13,770,274	**2.75**	4,586,923	**0.92**
Sardinia	3,178,438	4,885,325	530,290	898,432	**68**	9,492,485	**5.78**	12,115,385	**7.37**

a. Data 2003 unavailable for Calabria (data 1997), Molise, Sicily and Tuscany (data 1999), Liguria and Marche (data 2001), Sardinia (data 2002), and Piedmont and Basilicata (data 2004).

In fact, from these data it can be seen that the residential units of the periphery represent about 75% of the total amount of dwellings in urban areas. If we then consider that these suburbs are characterized by both internal and external finishings of a limited life span of the order of 30-40 years, it follows that the property heritage referable to modern times and to the 50's and 70's has needed or will require extraordinary maintenance works, the more extraordinary the older the buildings. This stock accounts for 72% of the entire urban residential heritage. As a consequence, the problem is particularly acute, and gives rise to an inevitable demand for building materials that is progressively on the increase, as reported in Fig. 4 [8], [9], [18], [19]. The sharp decline of the production of aggregates in 1986 is due to the crisis of the housing market at the end of 80's and the beginning of 90's.

IV. CONCLUSIONS

We are dealing with a demand for minerals that will become increasingly urgent, and will lead to impoverishment of the environment. As shown above, mineral resources have a great impact on the economic and social welfare of industrialized countries. The ultimate goal of mineral resource policies is not to limit the quantities extracted, thus affecting economic policies and resulting in a shortage of aggregates on the market, but rather to make a proper assessment of requirements in advance in order to plan amounts, methods and mining sites. Diverse complex solutions have been adopted in a number of European countries and may stimulate reflection and yield suggestions leading to adequate policies.

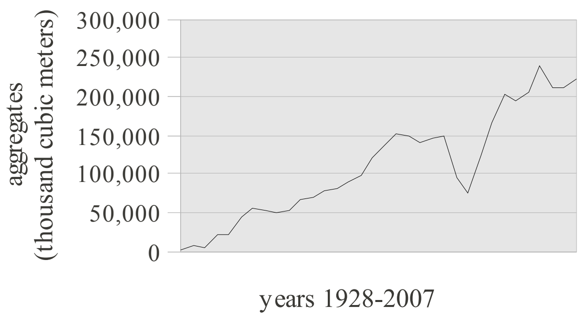

Figure 4. Production of aggregates for the building industry in Italy, for the period 1928 – 2007 (source: Fabbri; Vallario and Del Gaudio; British Geological Survey).

Among these we can point out the main two:

- An environmental policy that is extremely strict with mining activity.
- A policy oriented towards recycling (associated with exemptions and/or incentives).

Though we may generally agree with these environmental land policies, their implementation is a different matter, and in particular the modality used to satisfy the demand for minerals. Normally the policies at play are long term policies to satisfy a daily demand continuously on the increase, while it would seem advisable to link them with other short and medium term policies. The lack of such policies in fact creates serious difficulties for land management in terms of environmental conservation and economic development. We are convinced that the short and medium term approach should predict the assessment of the demand for minerals as part of town-planning organization in order to manage more appropriate land use based on extension and restructuring of buildings.

As regards recycling policies, while in some European countries (including Denmark, the Netherlands, Germany, United Kingdom), the market for recycled aggregates is growing more and more, in too many other EU states CDW (Construction and Demolition Waste) is scarcely reused. Fig. 5 compares the production of natural aggregates to that of recycled aggregates in the European Union during the years 2005, 2006 and 2008. In these years nearly 6% of the demand in the EU was covered by recycled aggregates, but this share would increase significantly if all countries started to encourage the recycling of CDW.

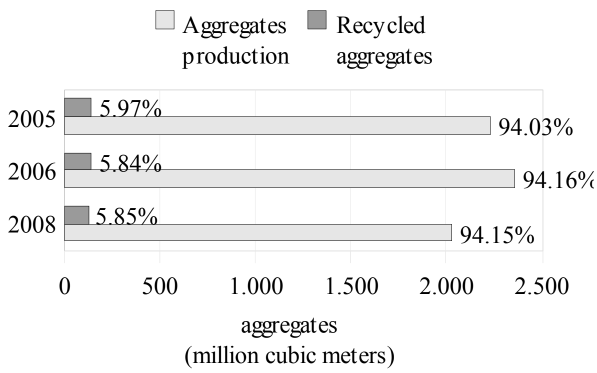

Figure 5. Production of recycled aggregates in the European Union during the years 2005, 2006, 2008 (source: UEPG, European Aggregates Association).

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