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The Mining of Aggregates in the Metropolitan Region of São Paulo

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1. Introduction

Construction aggregates, which consist of crushed stone and sand and gravel, are among the most abundant natural resources and are a major basic raw material used in construction. Despite the low value of the basic products, aggregates are a major contributor to and an indicator of the economic well-being of the nation.

Sand and gravel and crushed stone used as construction aggregates are mined near urban and rapid-growth areas because the marketplace is the urban environment and the materials are costly to transport. For example, the Metropolitan Region of São Paulo- (MRSP) in Brazil, which is the largest urban conurbation in South America[1] is one of the fastest growing metropolitan area in Brazil, with more than 17,5 million people spread over 39 municipalities, which are spread over 8.051km^2, and have a demographic ratio of 2.060 people per km^2 and an annual growth rate of 1,46%. The growth rate of the Metropolitan Region of São Paulo (MRSP) is directly linked to the intense industrialization and urbanization, which took place between 1940 and 1970. In 1996 the population of the MRSP already represented 10.6% of the national total and 48.6% of the State of São Paulo (SEADE, 1999). As a reference, this year, the income per capita was US$ 6.400,00 and the GDP US$102,8 billion, which is equal to 18,5% of the Brazilian GDP and 52% of the total for the State of São Paulo (EMPLASA, 2000).

The fact that the MRSP possesses a relative abundance of aggregates, thanks to its geological characteristics, has enabled the low-cost construction of an enormous number of buildings and public works to improve infrastructure and currently existing industrial installations.
However this accelerated urbanization occurred in an uncoordinated manner, which resulted in the generation of conflicts in the communities which were founded near to the existing quarries. Much of the housing belonging to these communities was built by the State or was a result of illegal land appropriation. The conflicts with the populations which have been growing in the areas of mineral exploitation have made inaccessible important reserves of aggregates.

This area, with historic high levels of production of construction materials and significant urban development, is typical of the metropolitan region of a country in development.

[1] The MRSP continues to be one of the three largest urban areas in the world, alongside the Metropolitan region of Tokyo, with 29 million, and Mexico Χιτψ, ωιτη 18 μιλλιον ρεσιδεντσ

Consequently, this area was chosen by Mining, Minerals and Sustainable Development Project – MMSD- as a case study to document the production and the availability of aggregates and the development of infrastructure. The objectives of this case study are as follows: the direct and indirect importance of the activity; how the material is transported and the scale of transportation needed; environmental impacts of this activity; concerns of those who live close to where aggregates are produced and alternatives for current and future supply.

2. The Aggregates Segment in Brazil and in the MRSP

In Brazil, in 1999, of the 1611 active mines, taking into consideration only those enterprises producing values superior to 10.000 t^3 /year, 80% of the total are linked to the civil construction area, with aggregates of 45,2 % (23,2% of gravel e 22 % of sand). (XI Universo).

In 2000, 380 million tons of aggregates were produced for civil construction, representing a growth of 11% in relation to 1999. Of this total, 155.8 million tons is made up of gravel and 226 million tons of sand[2]. The State of São Paulo was responsible for 32.3% of the national production. Other large state producers are: Minas Gerais (12%), Rio de Janeiro (9%), Paraná (7%), Rio Grande do Sul (6,4%) e Santa Catarina (3,9%).

Table 1
Primary Aggregates Statistics – Brazil –1998-2000

Breakdown		1998(r)	1999(r)	2000(p)
Sand	Production 10^6 m³	125.4	127.2	141.1
	Consumption t per capita(3)	1.2	1.2	1.3
	Price(1) US$/t	3.50	2.07	2.07
Crushed stone	Production10^6 m³	86.5	87.7	97.3
	Consumption t per capita(3)	0.8	0.9	0.9
	Price(2) US$/t	5.93	3.62	4.02

Source: Mineral Summary, 2001.
Notes: (1) Average price FOB - São Paulo State; (2) Average price FOB - MRSP; (3) Conversion Factor: 1,6 t/m³; (r) revised

The production of natural aggregates is closely related to the population and the level of industrial development of a specific area. The 1996 U.S. per capita consumption of aggregates was 8.7 metric tons. (TEPORDEI, 1999).

The 2000 Brazil per capita consumption of aggregates was 2.2 metric tons, these figures demonstrate the latent demand for aggregates which exists in the country, represented by high levels of need for housing (5 million homeless residents), basic

[2] Excluding energy minerals, gravel currently occupies second place in Brazil in terms of mineral production and third in terms of quantity produced (84.8 million m 3) and sand occupies third place in production value and second in quantity produced (135.7 million m 3). The quantity produced and the production value of aggregates puts the State of São Paulo in second place in national mineral production, only behind Minas Gerais (MINERIOS& MINERALS 2000).

sanitation and infrastructure, and the collapse of the road network, which has been aggravated by the accelerated rate of urban growth, as is the case in the MRSP, the most developed region in the country (MINERAL SUMMARY, 2001).

The production of gravel in Brazil is carried out by approximately 250 businesses, the majority of which are family concerns, and which were the source of, in 1999, around 15,000 jobs. The classification of the stone mines, in terms of their production, is the following: 60% produce less than 200,000 metric tonnes per year; 30% produce between 200,000 tonnes per year 500,000 tonnes per year and 10% produce more than 500.000 tonnes per year.

With reference to sand, around 2000 businesses are dedicated to the extraction of sand in Brazil, which in large part, are small family businesses, generating around 45,000 jobs in 1999. The distribution of sand producers, according to production is the following: 60% produce less than 6,000 m^3 per month; 35% between 6,000 and 15,000 m^3 per month and 5% more than 15,000 m^3 per month.

The use of gravel in Brazil is distributed in the following way: 50 % for the production of concrete, 30% asphalt paving, 13% for the production of cement artifacts and premoulds and 7% is destined for other uses. In relation to sand, 50% is destined for the manufacture of concrete and the other 50% for diverse aggregates. (MINERAL SUMMARY 2001.)

As mentioned above, the State of São Paulo is the largest producer and consumer of gravel and sand in Brazil and in this state the MRSP shines out as a great consumer of sand and gravel and a great producer of gravel.

Table 2 indicates the official reserves of gravel in Brazil, of the State of São Paulo and of the MRSP. An analysis of the data in this table reveals that the State of São Paulo possesses around 31% of the known reserves in Brazil, and that the MRSP holds 73% of the reserves of the State of São Paulo.

Table 2
Gravel reserves (1,000 m^3)

	KNOWN		INDICATED + INFERRED	
	1996	1997	1996	1997
BRASIL	3,878.417	4,422.329	2,495.609	2,868.653
SÃO PAULO	1,191.906	1,299.470	1,038.684	1,181.305
RMSP	885,523	949,146	724,245	692,014

Source: DNPM (1996 e 1997)

Table 3 indicates the official reserves of sand for civil construction in Brazil, in the State of São Paulo and in the MRSP.

Table 3
Sand Reserves (1,000 m^3)

	KNOWN		INDICATED + INFERRED	
	1996	1997	1996	1997

BRASIL	287,840	398,403	327,743	331,523
SÃO PAULO	175,760	277,593	182,606	169,480
RMSP	106,382	101,259	26,825	12,605

Source: DNPM (1996 e 1997)

The smaller value of sand reserves, when compared with gravel reserves is due to the fact that the cubage of the sand quarry does not have to be presented in order for a license to be granted. These figures show that the State São Paulo has around 61% of the known reserves in Brazil, and the MRSP holds 60% of the reserves in the State. It is worth emphasizing that, the majority of the potential reserves of gravel and sand in the MRSP have been made inaccessible due to urban occupation.

The production of gravel is well distributed throughout the MRSP, because of the importance of transport costs in the final price of the product. In these circumstances, the localization of the producers and their proximity to centers of consumption appears to be a crucial variable in effective competition.

The consumption of gravel in the MRSP went from 11.8 million in 1994 to 17, 7 m^3 in 2000, which represents an increase of 50% in seven years. Almost all gravel consumed in the MRSP is locally produced. The main barrier to the entry of producers from neighbouring regions is the distance required to commercialize the product which increases freight costs, which are aggravated by the tolls charged on the motorway. In addition to this the gravel producers are producing amounts well below their available capacity, which is approximately 40% higher than their current level of production.

In terms of sand however, the situation is different. According to information published by SINDAREIA, in 2000 the MRSP consumed around 30,000 m^3 sand, and only 15% of natural sand consumed is locally produced[3]. The MRSP has witnessed the entry of a substitute for natural sand onto the market: "artificial sand", which results from the washing of the powder of the crushed stone. The production of this substitute in the MRSP has already reached around 10% of consumption of sand and this figure is included in the aforementioned figure for gravel production.

In this way, around 75% of the sand consumed in this region is produced in places which are more than 100 km away, principally in the Paraíba Valley and the Ribeira valley. Almost all of the sand produced in these regions is transported by motorway [4].

The principal flows of aggregates link these areas of exploitation to the builders, the concrete merchants and the deposits of construction materials which are stocked by the distributing companies. According to some estimates, the demand for aggregates for residential projects

[3] There are studies for the utilization of sand deposited in the Tietê River, which is regularly dragged to avoid flooding. This utilization could supply 5% of the consumption of the municipality. (GORGUEIRA, 1997).

[4] There is small-scale transportation of sand by means of the railway between the Paraíba Valley and the MRSP.

– self-constructed and professionally-constructed buildings[5], houses and lower class housing projects by the builders –makes up a significant percentage of the total.

In order to transport the deficit of sand of the MRSP last year, (27 million m^3/year), 1,35 million journeys/year were necessary, or 5 thousand journeys/day by truck. Some estimates indicate that there are some 20,000 trucks permanently involved in the transportation of sand to the MRSP. (RANGEL, 1997).

The main motorway utilized in the transportation of sand is the Presidente Dutra – the main link between the States of São Paulo and Rio de Janeiro – which on many stretches seems saturated and incapable of supporting the high level of heavy trucks, above all on the stretches between Jacareí and Taubaté. During the autumn and the winter in the region climactic conditions tend towards the creation of thick fogs. Although there is no solid information or statistics about accidents on this motorway available, especially those involving trucks which transport sand, it is widely known that the number of accidents involving trucks in general is high and that those which transport sand represent a significant percentage of the total. (TEXEIRA JR, 1997).

The transportation of sand produced outside of the MRSP causes a huge overload on the highways of the city of São Paulo, mainly on the main routes for internal traffic such as the Marginais Tietê e Pinheiros.

The demand for aggregates is much less sensitive to variations in price than it is to the behaviour of macroeconomic variables, such as the income available to the population, population growth and economic policy. However, it is a matter of derived demand, one which follows the same pattern of behaviour of the economy and civil construction. The behaviour of prices of aggregates, especially that of sand, in the MRSP, is defined by the cost of transport and the economic situation.

In the MRSP, in the year 2000, in contrast to the last two years in which the activity, mainly that of gravel, was excessively low in price and was produced well below capacity, there has been a healthy recovery in prices and in production in the order of 10.3% and 14.2% respectively. (ALMEIDA et. al., 2000).

In Brazil, the mining of aggregates is subject to a range of regulations, whereby the three levels of government exercise their powers in relation to mining and environmental planning. The widest of these ambits is the federal, as can be seen in Illustration 1.

Table 4
Distribution of Governmental Powers in Relation to Environmental Protection and the Planning of Mining.

Mining Activity	Municipal Authority	State Authority	Federal Authority
Request for Concession or License	Laws of Use and Occupancy of the Land	Environmental License by IBAMA Commission	Approval or Denial

[5] In general, the builders acquire concrete manufactured in the concrete plants.

Mineral Exploration	Laws of Use and Occupancy of the Land	Environmental License by IBAMA Commission	Following of the Process Approval or Denial
Mineral Exploitation	License to function	EIA/RIMA analysis Environmental License by IBAMA Commission	Following of the Process and Mineral Inspection
Recovery of Mined Area	Definition of land-use in the future	Environmental License by IBAMA Commission	

Source: *SINTONI, 1994.*

One of the difficulties is in mapping out the borders of responsibility between these three spheres of authority (the Union, The State and the Municipality), with a view to clearly delimiting the jurisdictions of the monitoring of mineral activity.

There is a lack of real inter-governmental integration and also cooperation with civil society to create a mineral policy in the MRSP, which might establish parameters and criteria for mineral activity, and guarantee its permanence and continuity in terms of its role in urban areas, within norms and conditions which permit the preservation of the environment.

In the district of São Paulo there is an incompatibility between the current dispositions in the zoning laws and the mineral potential zones established in municipal legislation of use and occupancy of the land, which ignores the directives of Mining Project Director for the MRSP.

The environmental problems caused by the mining of aggregates, especially by the mining of sand, and the conflicts with other kinds of use and occupancy of the land lead to a growing diminishment of quarries available to meet the demand for sand in the MRSP, which also made it difficult for new enterprises to enter the sector.

In this district, there are many examples of gravel and sand quarries which were shut by the Council, owing to conflicts around the use of the land. In the Parelhos area, in the district of São Paulo, many sand quarries were closed for environmental reasons. Another region is that of Perus- Pirituba, which is an area with a great concentration of mines.

These impacts associated with the use and occupancy of the land, due to uncoordinated urban expansion, generate socio-environmental conflicts in the areas around the mines because of a lack of intervention methods which recognize the plurality of the interests involved. The conflicts generated by the mining of aggregates in the MRSP, due to an uncoordinated and uncontrolled expansion of housing allotments in outlying areas, demands a constant development in the management of this activity to avoid situations where an impasse is reached.

Mining in general, and more specifically that of aggregates in the urban area, provokes a combination of undesirable effects which might be denominated as being external. Some of these external effects are: environmental alterations, conflicts over use of the land, depreciation of neighbouring properties, the generation of degraded areas and, as has already been mentioned, disturbances in urban traffic. These external effects generate conflicts with

the community, which normally originate at the time of the inception of the business, because the owner does not inform him/herself as to the expectations, anxieties and worries of the community which lives in the proximities of the mining company. (BITAR, 1997).

According to SÁNCHEZ (1994), from the point of the view of the company there exists a tendency to see the impacts caused by the mining only as forms of pollution which are the object of regulation by public authority: pollution of the air and the water, vibrations and noises. According to this author, it is necessary for the businessman/woman to inform him/herself as to the expectations, anxieties and worries of the community, of the government – at its three levels of the technical body and of the workers of the businesses, that is to say the *stakeholders* – and not just those of the principal shareholder: the *stakeowner*. The perception of the environmental problems of each of the *stakeholders* is normally different to those of the *stakeowner*. The *stakeholders* involved in the mining within an urban area, as soon as they are informed of the activity are able to interfere in the management of the socio-environmental effects, in order to find solutions, which would minimize the number of conflicts.

The impacts of the mining of aggregates in the MRSP on the human environment take on a special importance due to the high degree of urban occupation, and are aggravated by the proximity between the mined areas and the inhabited areas. This is the case of the visual impacts, which result from high volumes of rocks and soil being moved and the size of the excavation or of the front of the mine. The environmental inconvenience can be felt even when the emissions are below the established environmental levels. On the other hand, it is rare for impacts to be felt on health when these limits are respected. (DIAS, 2001).

Currently, the mining of aggregates, principally that of gravel, in the MRSP, has made efforts to keep up with current demands on the environmental question, incorporating environmental management within the production process as part of the business plan, with the correct application of mining techniques and the meeting of determined parameters. (SINTONI, 1994).

This posture has transformed gravel mining, in the majority of areas, into an activity which is more acceptable to the community, due to the reduction in the discomfort generated by the vibrations from detonations and by dust. As an example, we might cite the case of Itaquera quarry, whose conflict with the community was resolved with the application of techniques which were more appropriate to the mining locality (reduction in the height of the bank, lighter loading and the use of more efficient explosives, among others). An efficient aspersion system was also installed which significantly reduced the emission of dust.

According to FREIRE 2000, the business professional must take preventative action in order to avoid conflicts. Cited as an example is the creation of a transition zone between the mining activity and the urban areas, or rather:

- The buying up of the areas around the enterprise. This alternative is not always possible because of the cost, principally for the small mining businesses;

- The setting aside of areas around the enterprise so that they might be used for activities which might live alongside the mining activity. Although the cost is lower, studies are needed to identify these activities;
- Improvement in the relations in the surrounding area between the property owners in the land adjacent to the enterprise;
- Planning of the mining operations and processing according to the legal dispositions which regulate the use and occupancy of the land in the region.

The solution to the conflicts resulting from mining in urban areas demands a coordination of the public authorities which work in the mineral sector, together with civil society and the entrepreneurs[6], so that norms and procedures with clear criteria might be implemented.

5. Final Considerations

The mineral sector of the MRSP has made great efforts to keep up with the current demands being made on behalf of the environment. The businesses are, in the majority, applying more modern techniques which are more environmentally friendly. In the majority, they see the necessity of meeting the environmental costs themselves and, already recognize as legitimate the claims made by communities through public action.
The production of gravel sand might become the biggest differential between the stone merchants in the MRSP, who are contributing to the balancing out of the sand equation in the MRSP.

Construction aggregates are widely distributed throughout the MRSP and occur in a variety of geologic environments, however, they are not universally available. Some areas lack quality aggregates, or existing aggregates deposits cannot be mined for a multitude of reasons; but economic factors require that pits or quarries be located near the population centers. However, residential communities usually require that mining of aggregates be conducted far from their boundaries. Thus, competing land-use plans, zoning requirements, and various regulations frequently prohibit extraction of aggregates near populated areas.
Because the demand for aggregates will continue and, most probably, will grow in the future, provisions to assure adequate supplies will have to be made.
Long-range planning and zoning regulations will have to take into account current and future community needs for this valuable natural resource. All groups and individuals will need to work together to ensure adequate community and environmental protection, while ensuring the availability of aggregates at a reasonable cost that will allow growth and prosperity.
Today, it is recognized that everything that is used must start with raw materials that are mined and that the Earth's resources, however vast, are finite. It is also understood that wise stewardship of the environment is necessary to preserve natural resources for future generations. To that end, the crushed stone and sand producers have to meet all

[6] Currently, the entities, which support the aggregates sector, exercise important political influence and together with the public bodies responsible for the development of the activity, are trying to influence decisions related to the regulations at a State, Federal and Municipal level. The gravel sector is represented by a sponsoring syndicate, SINDIPEDRAS and the sand sector by SINDAREIA.

environmental regulatory requirements, and are encouraged to exceed what the laws and regulations require. Consequently, their work is planned with a clear understanding of their role in conservation and land reclamation. The results of successful reclamation projects can be seen around the country in housing estates, recycling centres[7], shopping malls, community parks and lakes, areas of historic and natural interest which have been preserved and wildlife refuges.

[7] Itaquera quarry is planning to construct a recycling center, for the production of recycled aggregates.

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