Carinthia University of Applied Sciences

Work Package 3: Environmental Impact

Cleanstone Project

Projektcode:

ITAT 1056

Program:
Interreg V-A Italien-Österreich - Aufruf 2018

Partner:

Università degli Studi di Udine – Dipartimento Politecnico di ingegneria e architettura – DPIA

Università degli Studi di Padova

Carinthia University of Applied Sciences

Confartigianato Vicenza

E.C.O. Institut für Ökologie

Contents

Work Package 3: Protocols to reduce the environmental impact of stone processing

Environmental analysis of the cutting process of stone materials

With the purpose to analyze the extraction, process and cutting of the stone and the environmental impact of the different stages, different quarries were visited (see Fig. 1). For this purpose, four quarries were visited. Two quarries from Italy and two quarries from Austria. The following chapter describes shortly the materials extracted from each quarry, the process of them and the waste that is generated as a by product. The detailed information of every quarry will be described in the following sections.

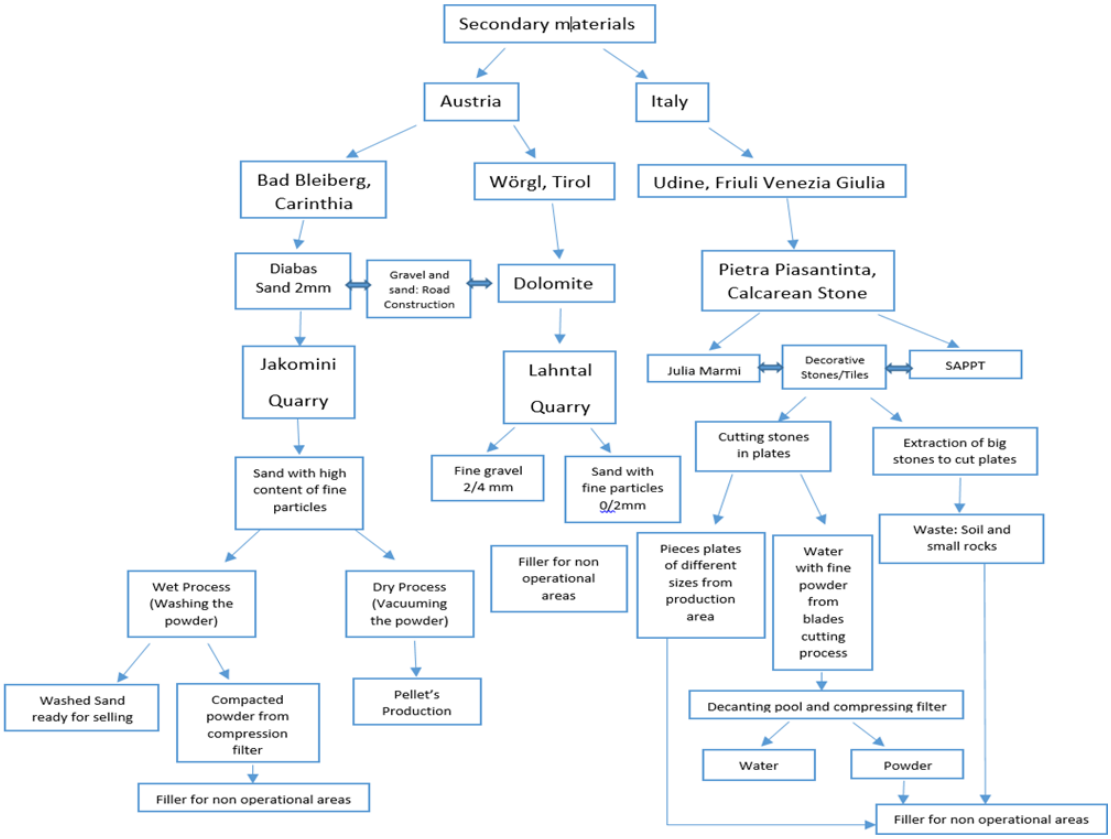

Fig. 1: Quarries visited: secondary materials produced

Italian quarries: Environmental analysis of the cutting process

- Place: Udine, Italy
- Companies visited: Julia Marmi Decorative Stone Production site and quarry; SAPPT quarry

- Goal: Analyze of the cutting process in the production site
- Type of rock: Pietra Piasantina. Calcarean stone. Sedimentarean rock.

Julia Marmi Decorative Stone Production site and quarry

The quarries visited are located in Udine, IT. The type of rock extracted in both quarries is extracted is Pietra Piasantina. This material is extracted in huge rocks that then are cut into slabs of different thickness for decorative stones purposes. That is why, the method of extracting the material is by pulling out the rocks with a backhoe (see Fig. 3). Other extracting methods like blasting are not used since the company needs entire big rocks to cut them in slabs afterwards.

Fig. 2: Piasantina Rock

Fig. 3: Extraction with Backhoe

Fig. 4: Slab cutting

Fig. 5: Final product

Once that the big rocks are extracted they are separated to be transported to the main building to be cut in slabs (see Fig. 2 - Fig. 4) and to be processed with different types of finishing depending on the final purpose of the product. The final products can be tiles, sinks for bathrooms, kitchen counters and decorative stones in general (see Fig. 5).

From the extracting process in the quarry it can be seen, that only the big stones are needed. However, soil and small rocks are also extracted and considered as waste. This is used to refill non-operational areas from the quarry. After the extracting process, trucks transport the big rocks to the factory. The rocks are transported into the building to start the cutting

process using a bridge crane. Some of them are cut with a big saw (see Fig. 6) and some of them are cut with a multi blade marble block sawing machine under a shower of water (see Fig. 7). The shower of water avoids the heating up of blades.

Fig. 6: Stone cut big saw

Fig. 7: Multi blade marble block sawing machine

The multi blade sawing machine cuts the rocks in slabs leaving them ready for a secondary cut phase. The smaller pieces of rock that are cut with the big saw in Fig. 6, are then cut in slabs with smaller sawing machine shown in Fig. 8 which needs also water to cool down its blades.

From the technological point of view, the cutting process it is made with old technologies that could be changed in order to reduce the amounts of powder generated. Diamond wires could be used, however this technology can be expensive for small local familiar companies.

The multi blade sawing machine makes the primary cutting. This equipment cut the rocks in slabs. With a smaller multi blade sawing machine (seeFig. 8) smaller pieces of rock are cut. The water used for cooling down blades contains high amounts of fine powder (see Fig. 9) that needs to be separated from the water. This is also considered as a secondary material of the production process.

Fig. 8: Multi blade sawing machine

Fig. 9: Fine powder with water

The water treatment consists in a decantation process that takes place in sedimentation pools. The powder is separated from the water by using a floculant. After that, the powder goes into a compressing filter that takes the remain water out of it. The powder is than almost dry. Finally, the dry powder is transported and disposed in non-operational areas of the quarry in order to refill the areas where the rock was extracted (see Fig. 10). The consistency of the powder is very plastic.

In Fig. 11 it is possible to see the disposal area, in other words the refill area with the secondary materials product of the extraction, cutting and decanting process. In this picture, it is possible to see the fine powder from the cutting process and rests of cutting the stones all mixed.

Fig. 10: Disposal of Fine powder with pieces of cut stone of production process

Fig. 11: Refilling area: Disposal of Fine powder, pieces of cutting, soil and small rocks

It could be seen that after some time the refilled areas are covered by vegetation that sometimes is planted and in another cases it also grow by itself thanks to the very wet weather of Udine (see Fig. 12).

Fig. 12: Julia marmi's recultivated area

Fig. 13: Julia marmi's recultivated area

Julia marmi's owners could really turn the landscape of a quarry into a nice park for recreation. They planted chestnuts trees, apple trees, they have sheep and the place looks

like if there would have never been an extraction area of a quarry in this place. The fruits produced in these old refilled areas that now are green fertile areas are sold in the local market. They also have made a theater where once a year all of the people of the town around is invited to visit the place and make a touristic tour (see Fig. 13 - Fig. 15).

Fig. 14: Julia marmi's Theater

Fig. 15: Julia marmi's recultivated area for sheep

The production of tiles they different steps of finishing (see Fig. 16) to get different textures on the tiles. Flaming, brushing, polishing and hand hammer finishing techniques are used to get different textures. These processes do not really generate secondary materials.

Fig. 16: Finishing process

SAPPT quarry

At the moment of visiting the extraction area of the company SAPPT the quarry was not operating because of the pandemic context. In this quarry, two different methods of extraction were appreciated. The outer layers of the rock that are not suitable for the production of decorative stones are blasted and transported with a backhoe to the disposal area. The aim of this is to reach the part of the rock that it is useful for decorative stones (see Fig. 17).

Fig. 17: Blasting and cutting process

Once that the useful part of the rock for decorative purposes is reached, the rock is cut into cubes with a diamond wire machine, in this way it is possible to get entire cubes of rock.

The usage of diamond wire it is better since the cut looks clean and perfect, it is less probably to loose parts of the rock that with other methods. The Diamond wire needs water to avoid the heating up of it during the cutting. This tool is also more efficient since the amounts of powder produced during the cutting are less than another methods of cutting like the armed chain cutting machine.

The production area where the tiles and decorative stones are shaped and cut wasn't shown since the process is very similar to Julia Marmi. The secondary materials produced are also disposed in non-operational areas and are mainly pieces of slabs or cubes from the production area; small rocks from the extraction site and fine powder (see Fig. 19) from the compressing filter (decantation process of the powder and water generated in the cutting process). In the non operational areas visited, it was possible to see that it was densely forested with natural vegetation and vegetation planted by the company (Fig. 18).

Fig. 18: Reforested non operational area 10 years later

Fig. 19: Plastic fine Powder from press filter

Austrian quarries: Environmental analysis of the cutting process

Lahntal quarry

- Place: Lahntal 6, 6300, Wörgl, Tirol, Austria.
- Company: Mineral Abbau GmbH - Steinbruch Lahntal
- Goal: Analyze of process of aggregates for road construction.

- Type of rock: Dolomite

The Lahntal quarry is located in Wörgl, Tyrol. The visit was made in cooperation with colleagues from the Insitute of Ecology from Klagenfurt, Carinthia, AT. The quarry is located in a commercial area where there are shopping centers and resident houses, this means that the traffic of trucks getting the material out of the quarry is mixed with the normal traffic of the city of Wörgl (see Fig. 20). The type of rock that is extracted is Dolomite (see Fig. 21).

Fig. 20: Location of the Quarry

Fig. 21: Dolomite

Extraction Process

This material is crushed and used as gravel or sand as a construction material, that is why, the method of extracting the material is by blasting the rocks. The extraction process was made in the shape of steps along the mountain. The explosives are inserted into the rock massif and then blasted. For this purpose, a drilling machine is used to make a perforation through the rock where the explosives are placed into (see Fig. 22 - Fig. 25).

Fig. 22: Blasting method

Fig. 23: Perforation hole made by drilling machine

Fig. 24: Drilling machine

Fig. 25: Transporting Cycle

Once the rock is blasted, the blasted material is collected with a Crawler Excavator and loaded into a truck.

The truck dumps the material into a tunnel drilled into the mountain. The tunnel is a conduct that connects the area of extraction up in the hill with the processing area down in the quarry. In this way, the material doesn't have to be carried downhills in trucks to the processing area. The material is dumped in this conduct and the material reaches the processing area by gravity. This reduces the transportation costs and the carbon emissions.

Fig. 26: Entrance of the tunnel

Fig. 27: Truck dumping material

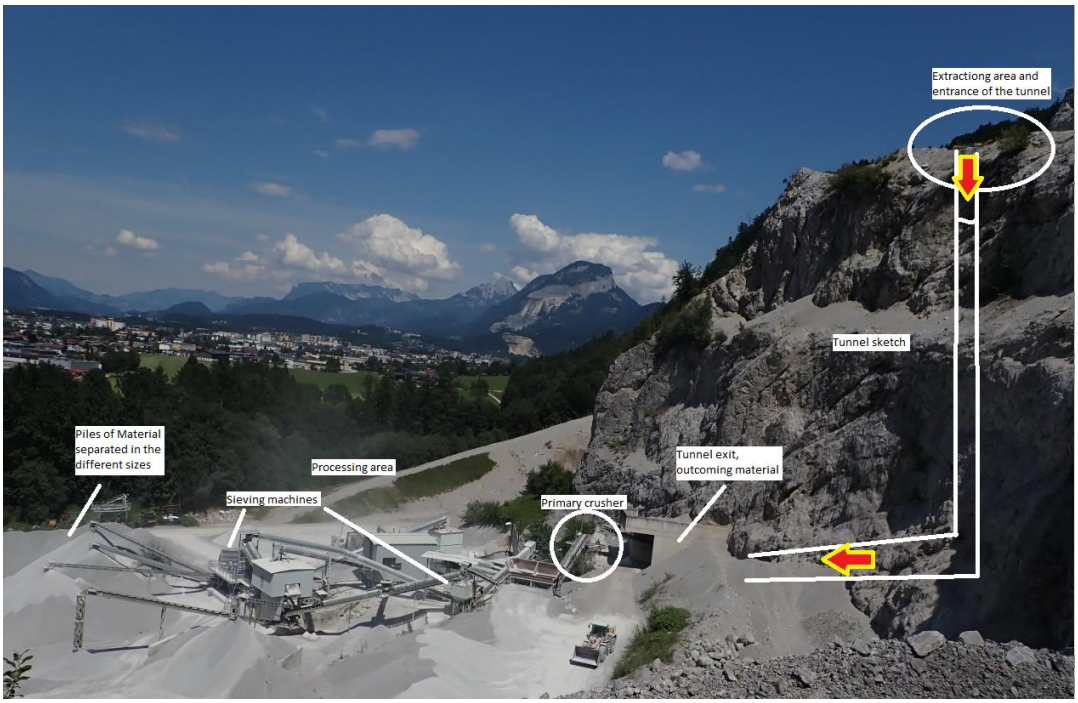

Fig. 28: Processing area

Once the material is dumped in the tunnel, it reaches the foot of the mountain where the processing area is. There, is deposited onto transporting belts that dump it into a primary crusher. Afterwards, the material is crushed and sieved into different sieving machines. The material is sorted into piles with different sizes of grains.

Fig. 29: Material received in the base of the tunnel

Fig. 30: Sieved material ready to be transported

When the sieved material is categorized in piles, a front loader machine loads the trucks that will take the material to the construction site. The material is stored for commercialization or for road construction activities developed by the company. The fractions of material that the company produces are the following:

Tab. 1: Percentage of each fraction

Particle size (mm)	Fraction in percentage (%)
0/2	35
2/4	19-20
4/8	19-20
8/11	14-50
11/16	12
16/22	9
22/32	3
32/70	1

Regarding the production of waste, the company produce an excess of material of the sizes 2–4 mm and 4–8 mm (see Fig. 31), which cannot be used or commercialized. These materials where sent to the Laboratory of Materials of the Fachhochschule Kärtnen to make further investigations of possible usages of this material. Other problem that the company faces, it is that the split stone produced does not present high hardness and it is easily breakable by pressing or hiting it with it hammer.

Fig. 31: Material 2-4mm

The following diagram was provided by the company and explains the process in detail:

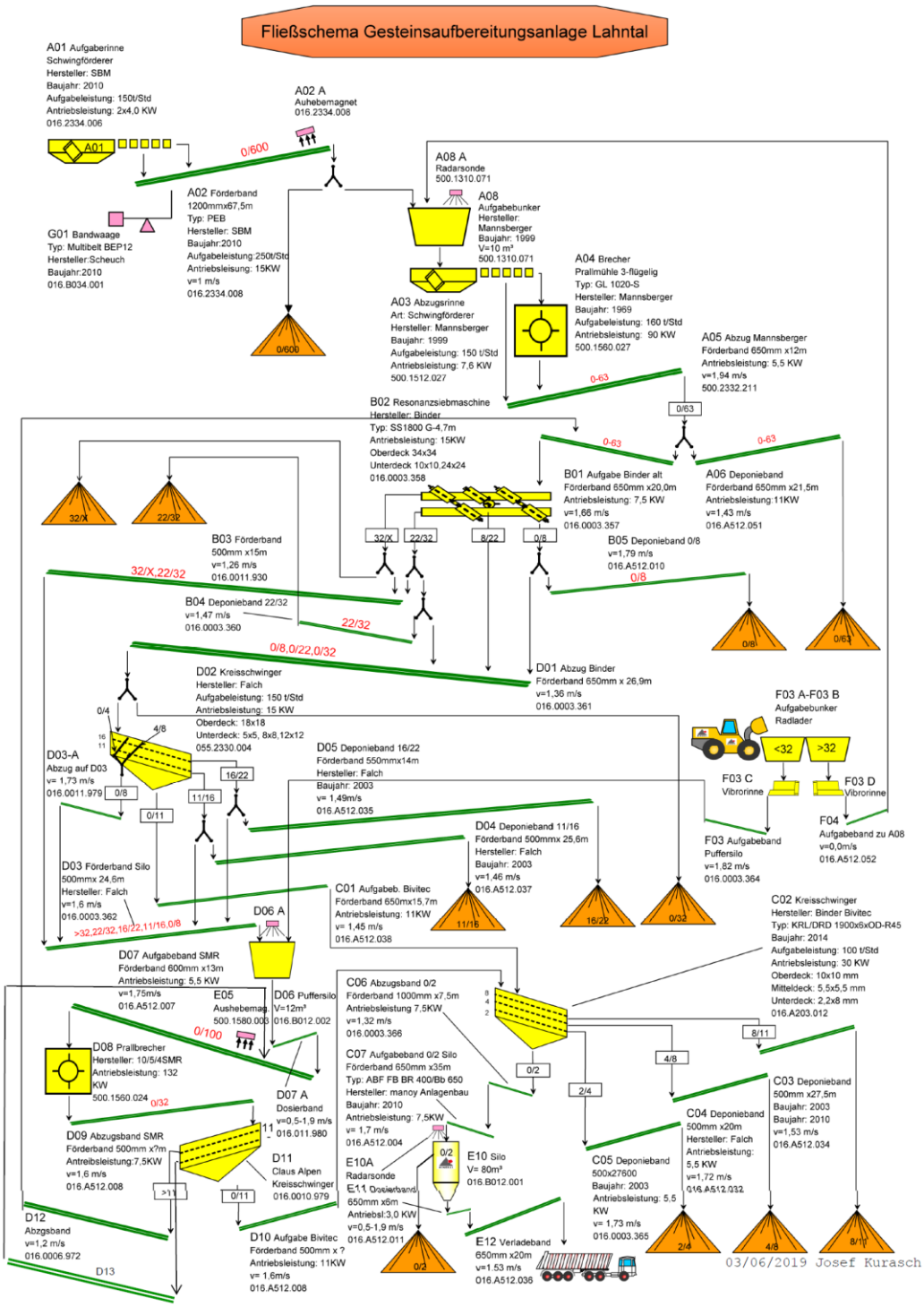

Fig. 32: Detailed Process

Reforestation Plan

The company reforest the affected areas after the extraction of the material. The areas are separated in two types: flat areas and sloped areas. For the different areas, different species of plants are needed since not every plant grows on sloped areas. For the flat areas, they plant trees from the same species available around the area. They plant one tree per square meter. The trees are watered once a day with a truck that drives up in the hill with a water tank. For the sloped areas, the company buys special seeds that are capable to grow in slopes. The problem of this type of seeds is that they are expensive, the price is about 2.000 EUR per kilogram. The following pictures show some types of trees that are already planted (see Fig. 33 - Fig. 34).

Fig. 33: Trees to be planted

Fig. 34: Reforestated area

Bad Bleiberg quarry

- Place: Bleiberger Str. 172, 9530 Bad Bleiberg
- Company: Mineral Abbau GmbH - Jakoministeinbruch Bleiberg
- Goal: Analysis of the process
- Type of rock: Diabas

The quarry is located in Bad Bleiberg, AT. The type of rock that is extracted is Diabase. The material extracted is used for producing gravel or sand for construction purposes. The method of extracting is by blasting the rocks. As you can see in Fig. 35 there are different colors of the same rock along the massif. This is because of the different geological processes as it is described in the petrographic analysis made by TPA GmbH listed in Annex 1: originally, it was a tholeiitic basalt, which experienced a continental rifting. Then this rock was metamorphically overprinted as part of an orogenic phase. During this orogenic phase, the rock broke and because of tectonic movements, was transported to the surface of the earth. Now at days it is possible to see that this type of rock has three different colours.

Fig. 35: Diabas massif

The shape of the plates are in inclinated. This is also because of the different geological processes: maily cause of continental rifting.

Extraction Process

The extraction process was made in the shape of steps along the mountain as it can be seen in Fig. 41. The method of extraction was using explosives which are inserted into the rock massif and then blasted. For this purpose, a drilling machine is used to make a perforation through the rock and then the explosives are placed into this perforation. Once the rock is blasted, the blasted material is collected with a Crawler Excavator and loaded into a truck that transports this material to the down part of the process area where it is crushed, sieved and sorted into different piles of different sizes (seeFig. 36 - Fig. 37).

Fig. 36: Transporting Cycle

Fig. 37: Processing area

When the truck arrives to the processing area, the material is dumped into a conduct and then onto transporting belts that dump it into a primary crusher. Afterwards, the material is sieved into different sieving machines and categorized into piles according to the grain size. In Fig. 37 it possible to see the three piles of the different colors and types of rocks. These kind of rocks besides having different colors, they also have different strength properties. Depending on this, the rocks are mixed to find the most appropriate granulometry and properties required for the construction of roads and streets. Taking in consideration that the aim of this project is to recycle the waste generated by quarries, it

was asked to the authorities, which was the main problem of the quarry regarding waste materials. The issue that the company faces, is that they produce material of the size 0/2 mm with a high amount of fine particles passing 0,063mm sieve. The amount of fine powder in the sand is above the 12%, this is the reason why the material doesn't meet the granulometric requirements for asphalt and concrete mixes. Therefore, the company developed a washing system in order to wash the fine powder out of the sand and make it suitable for road construction. However, this process is very expensive. The sand is conducted to a sedimentation tank that contains water with flocculants (see Fig. 38). In this conditions, it is possible to make the finer particles sediment and separate the fine powder of the bigger particles of the sand. The final product of this process is wet sludge (see Fig. 40). In order to extract the water from the sludge, this is compressed in a filter press. The filter press consist of a serie of plates that compress the sludge to extract the water out of it and it is possible to get a dry block of powder that can be used for another purposes (see Fig. 39). At the moment, the powder is transported and used to refill areas that are not operational anymore.

Besides this washing system, the company also has a vacuum system to extract the dry powder that is left while the material is being sieved. With this dry powder another industry makes pellets and sell them as dust flour in shape of pellets since they are useful for fertilize plants and gardening purposes.

Fig. 38: Sedimentation tanks

Fig. 39: Filter Press

Fig. 40: Dry Sludge obtained

The following diagram shows the different steps of the production and transportation:

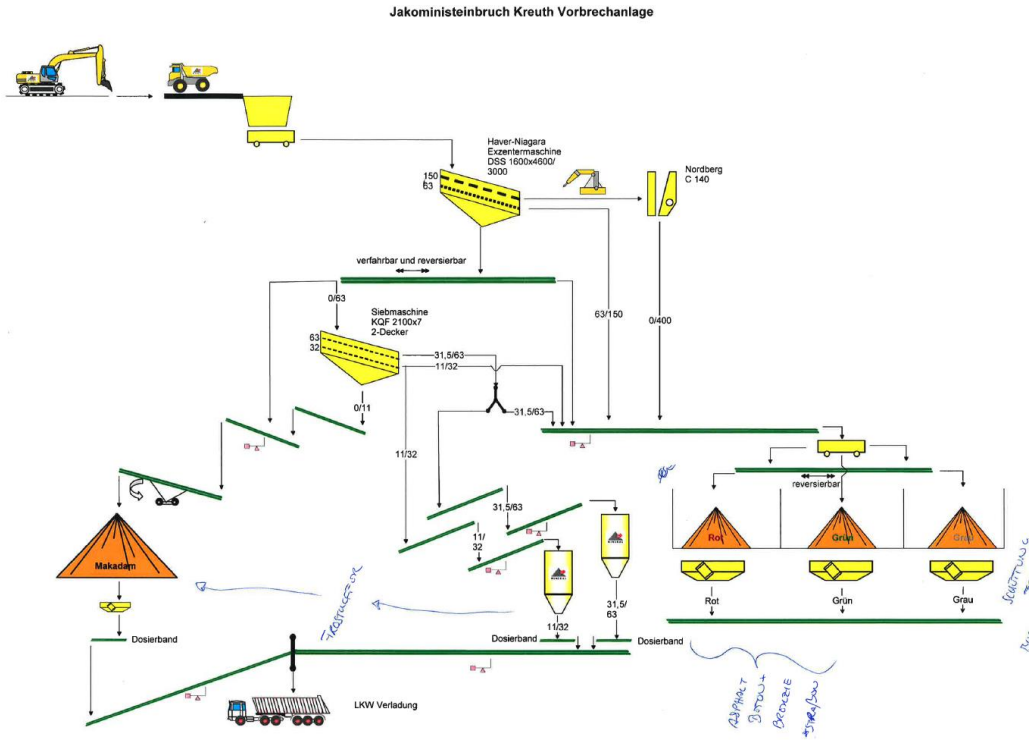

Fig. 41: Primary crusher

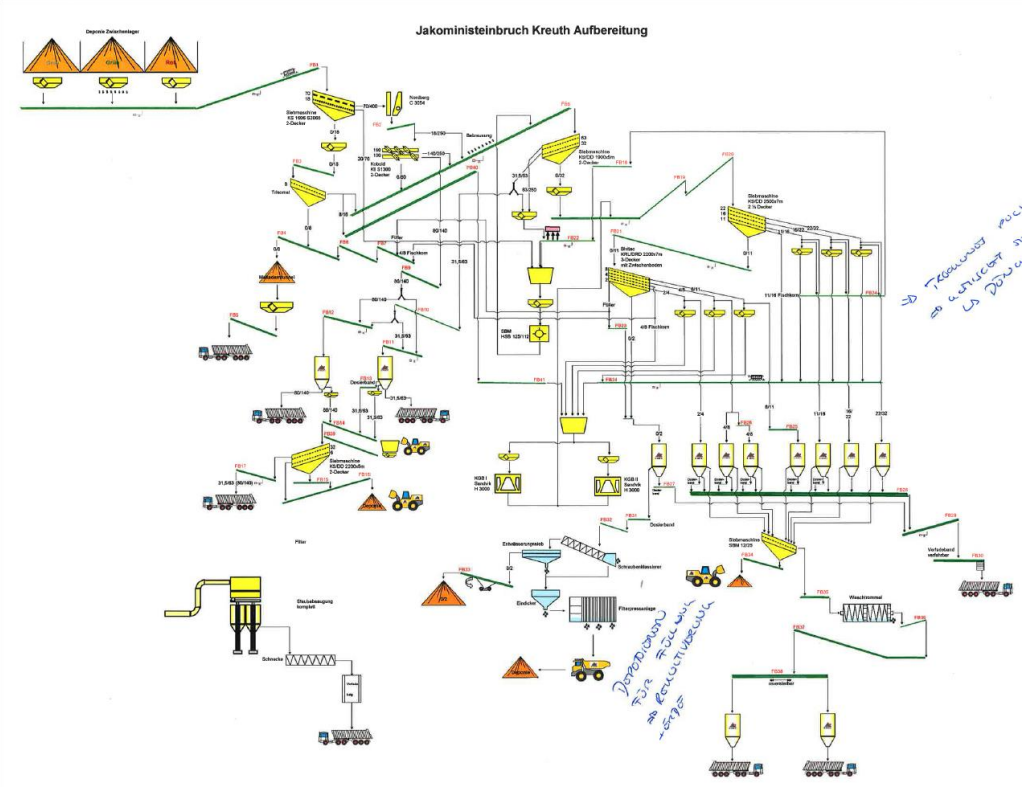

Fig. 42: Preparation of the material

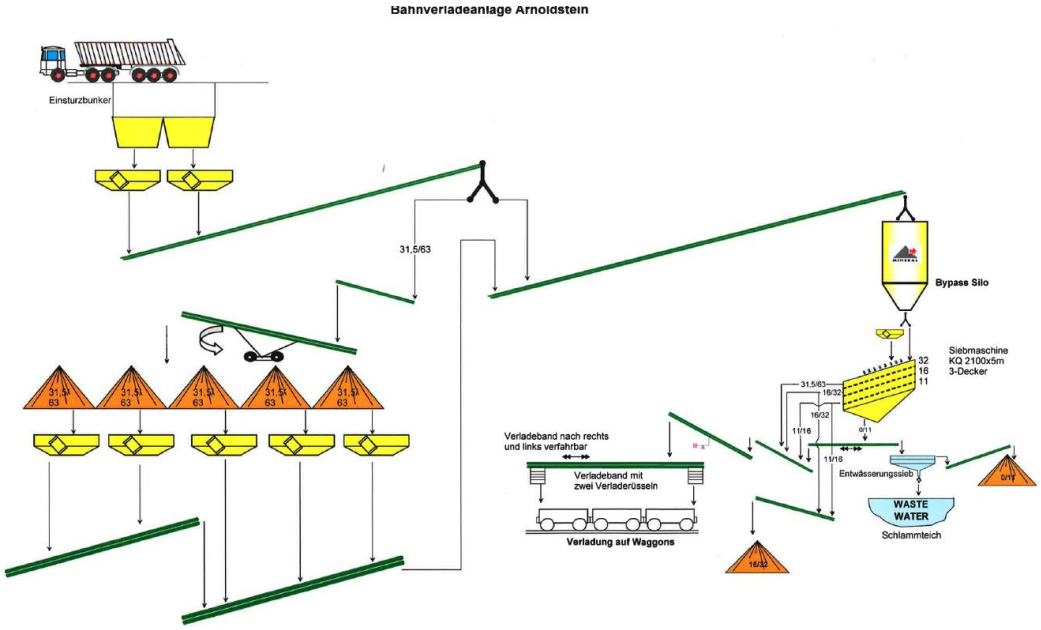

Fig. 43: Rail loading facility

Process analysis of the three quarries visited

Tab. 2: Process analyze of the visited quarries

Comparison of process technologies				
	Piasentina Quarry, Udine - Italy	Dolomite Quarry, Wörgl - Austria	Diabase Quarry, Bad Bleiberg - Austria	Piasentina SAPPT Quarry, Udine Italy
Preparatory work – required machines	▪ Backhoe ▪ Multi blade sawing machine	A three dimensional survey from the quarry face is done so the blasting engineers know how to put the explosives in a safe way. A detailed drilling and blasting plan is prepared for this step. If there are voids in the massif of the mountain, less amount of explosives are needed, in the case of bulges a higher amount of explosives is required. The holes are drilled according to the prepared drilling plan using a remote-controlled drilling contractor machine. After that the holes are done , they are surveyed again to check if their position matches with the designed blast position.	For the drilling and blasting services, the Mineral GmbH falls back on a subcontractor. The blasting engineers draw up a digital three-dimensional survey from the quarry face and profile measurement in order to obtain optimal rock material for further processing. A precise analysis is important for the greatest possible safety by blasting processes. The drilling device drills the holes in two rows at an angle of 80 degrees and the drill hole depth is 20 to 21 meters. The used explosive is called Emulex. ▪ Drilling contractor machine ▪ Crawler excavator ▪ Dump truck ▪ Truck	▪ Diamond wire machine
Rock loosening process	The extraction takes place by pulling out the rocks with a backhoe. Other methods like blasting are not recommended since the company needs entire big rocks to cut them in slabs afterwards. The usage of Explosives can generate fractures in the massif, and then the marble slabs can have undesirable failure lines. Smaller rocks, which are generated during the loosening process, are used as landfill in non-operational areas.	In the next step the holes are filled with high explosives and the face of the quarry is blasted. A loader machine loads the loosen material into dumper trucks that transports the rocks to a tunnel that goes perpendicular through the mountain. This tunnel connects the mining area with the processing plant area. So the material does not have to be transported there via another route, but is simply poured into the tunnel. The rock only reaches the area of the primary crushing plant through the gravity. This saves transport costs and reduces CO_2 emissions at the same time.	After the holes are filled with Emulex and the face of the quarry is blasted, a backhoe loads the material into dumper trucks, which transports the loosened rock to the processing area into the primary crusher. Through this process 500.000 tons per year are processed. The largest amount of mining waste material is generated during the processing of split. (40.000 tons per year). Sand produced during each processing step is declared at 6000 tons per year.	In this quarry two different methods of extraction were appreciated. For the outer layers of the rock that they consider that are not suitable for the production of decorative stones, they blast the rock and they transport the blasted stones with a backhoe to the disposal area. The aim of this is to reach the part of the rock that it is really useful for decorative stones.

Preparation process	After the stone block has been transported to the processing area, a gantry crane unloads the truck in the factory site and then the cutting process starts. For this process the company uses two different types of cutting machines ▪ Big simple saw ▪ Multi blade marble block sawing machine	The material is fed through the three crushing stages via a conveyor belt. Every stage produces progressively smaller sized stones. For the first processing stage a jaw crusher is used the following crushing stages take place by means of cone crushers. No water requirement in the direct processing only for dust binding in the reloading area. Approx. 150 m3 of water is required per year in the reloading area.	The jaw crusher on the first stage is ideal for break up hard rock and is working according to the pressure crushing principle. The material will be crushed until the grain size is smaller than the adjusted crushing gap. After that, the output is placed in a primary pile from where the secondary crusher (impact mill) is fed via conveyor belts. The impact mill is especially suitable for crushing agglomerations in bulk material. The impact crusher operates on the principle of impact crushing. The material to be crushed, is caught by fast rotating rotor, strongly accelerated and thrown onto a stationary impact mechanism, the impact rocker arms. From there, it falls back into the rotor's impact circle. In this way, the crushed material is broken further and further until it can pass through the gap between the rotor and the impact rocker arms. Part of the material finally enters the cone crusher – cone crushers provide standard cubic final grain sizes in the 2nd and 3rd crushing stage. The quality of the final product depends mainly on the insertion of the cone crusher in the whole preparation process. Dust is generated at each processing step, approximately 600to per year.	Once that the useful part of the rock for decorative purposes is reached, the rock is cut into cubes with a diamond wire machine, in this way it is possible to get entire cubes of rock. The usage of diamond wire it is better since the cut looks clean and perfect, this is an advantage since it is less probably to loose parts of the rock that with other methods wouldn't be possible to use. This wires, need also water to avoid the heating when cutting and to cool down but the amounts of powder are less than another methods of cutting like the armed chain cutting machine.
Loading and transport	In this quarry, the rock is transported by the company's own trucks directly to the workshop for further processing. The surrounding customers pick up the products themselves or they are delivered from the workshop.	There is no increased dust generation here, as the dissolved material is only transported 2 kilometers to the mixing plant.	The bulk material for immediate transport is stored in the silos from where the trucks are then loaded for distribution. On the site there are still bulk materials with grain sizes from/to. Before the trucks leave the site, they pass through a washing line to prevent dust dispersion. As the plant has a fully automated truck and rail loading system and has been extensively modernized in recent years, the quarrying and processing process has already been optimized	In this quarry, the rock is transported by the company's own trucks directly to the workshop for further processing. The surrounding customers pick up the products themselves or they are delivered from the workshop.

			here. Due to its location, the quarry has excellent connections to the road and rail network. The dust on the roadways is bound with water in order to avoid an increased amount of dust.	

Conclusion

The aim of this document was to collect information and analyze the environmental impact of the different phases like mining, transportation, storage and processing of the quarrying process. The life cycle assessment is the tool to quantify the potential environmental impact produced by these activities. The identification of the impacts aims to create a list of best practices that will lead the quarry sector to a cleaner production. The principle of reduce, reuse and recycle will allow the now called 'waste materials' to be considered as 'secondary raw materials'. This change of perspective will lead to include and contemplate the secondary raw materials in national guidelines and standards and reinsert them in the market as a valuable material. The strategic transportation, the optimization of the cutting and blasting process, the digitalization of the quarrying sector are some of the main aspects to improve in order to reduce the environmental impact.

List of figures and tables