QUARRY RECLAMATION FOR HIGH PERFORMANCES AND SOCIAL EVENTS

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ABSTRACT

The final destination of dismantled sites after quarrying is frequently of a low profile such as for waste disposals. The consequent environmental degradation, due to the extraction activity, does not allow site reclamation, and the landscape gets even worse by the new use of the site. This situation is obviously not socially accepted when the quarry is located close to inhabited areas. The present study started from the analysis of the problems related to the reclamation of a site, near the town of Ardea, Latium - Italy, quarried in the past. It has been therefore analysed the surrounding land with the aim of pointing out the interaction of the site with the anthropic system. As a conclusion of this analysis it has been revealed the interest to reserve the site for social events, during the whole year, and for artistic performances, during the holiday season. The main project features have been analysed: landscape, geology, slope stability, ground characteristics, climate, vegetation, demographic dynamics, state of the roads, inhabitants and settled places, town-development tools and site-state before quarrying. A proper cognition of the land, about its natural and anthropic aspects, has been essential for this type of work. The study has been carried out in different scales: town, district and quarry scale. Every scale allowed to point out the different solutions in relationship to the complexity of the remediation project.

INTRODUCTION

Starting from 1987 by the Bruntland Commission it has been affirmed that, for a sustainable development, the stock of the life quality for future generations should be higher than the one at present time (Pearce et al., 1991).

Following this principle all the projects concerning mine closure not only have to achieve soil, water and air standards but also to obtain a new target for the restored site. Besides, taking into account the growing request for free time activities, which are usually linked to higher economic level of the inhabitants, the use of the dismantled area for social events and high performances has to be taken into consideration after quarrying. The different kind of final destinations for social activities can be classified under the following target categories: naturalistic-recreation, sport structures, productive plant and naturalistic-didactic-scientific.

The aim is always to reach suitable environmental, social and economic objectives. As a matter of fact through naturalistic restoration it is possible to improve the environmental quality of the dismantled site, even if the pre-quarry conditions are not feasible, either through the creation of new naturalistic site or through the addition of characteristics of naturalness (Malecevschi et al., 1996).

If the site is intended to social activities it also necessary to reach safety conditions for the quarry face, to realise suitable supports to the recreational activities, to maintain vegetation and to schedule periodic controls of functionality of the structures and the infrastructures. Once all these operations have been completed, it is possible to get profits by social events and high performances can be organised into the restored site.

METHODOLOGY FOR QUARRY RECLAMATION

The quarry reclamation project consists of different steps. The study of the site leads to the choice of the objectives, linked to some main operations including the restoration of the landscape, levelling of the slopes, drainage of the site and installation of technological services, sowing and planting of suitable vegetation, settling of functional devices. Maintenance has to be foreseen for all the elements of the reclamation project.

Site analysis

The analysis of a site has to be carried out under different scales: town, district and site. In each scale it should be possible to point out the landscape, geology,
slop stability, soil characteristics, vegetation, climate, demographic dynamics, viability, town planning means, the former utilisation of the site and the potential users depending on the new target. Once the site has been characterised, the further step is to look at the project targets to set in accordance to the surrounding territory inclination.

Therefore it is of importance to refer to the plan of the surrounding towns in order to survey all the infrastructures (commercial, productive, industrial, administrative, tourist and road) and the green and protected areas. The relationship between the site to be restored and the surrounding land, by means of proper road connections, has to be highlighted. In particular, for the site target related to urban services, it is important to take into consideration the road system at different scales and the location of the functional services in the nearness (Gatti, 1993).

Restoration of the landscape

The restoration of the landscape strictly depends on the quarrying technique and on the project target. The main aim is to achieve safety conditions and suitable aesthetic-perceptive valence (Bradaschi, 1998).

Some of the methodologies for quarry restoration are the following:
- reduction of the slope of the benches' rise by filling the slope base by means of excavated materials and terrain, adding organic material and/or fertilisers (Malcevschi et al., 1996);
- reduction of the average slope of the quarry face by cutting of the edge of the scarps and replacement at the base;
- improvement of the slide resistance of the slopes by lowering of the barycentre of the accumulated material or through the use of gabionades;
- improvement of the slide resistance of the slopes by removal of the accumulated materials.

Once it has been obtained steadiness conditions for the quarry face, it is important to promote the restoration of the vegetation adopting one or more of the following techniques coming from naturalistic engineering (Mazzoni, 1998):
- vegetative covering, that consists in placing sown terrain into the fractures and ravines of the slope; the terrain can be kept in situ by geo-nets;
- hydro-seeding, consisting of mechanical spraying of a mixture of water, seeds, natural fertiliser together with binding agents, herbaceous and brushwood species, after putting suitable geo-nets on the slope;
- vegetative cuttings, utilising zinc-plated net containers filled with terrain suitable to be sown;
- live grating, which is a method adopted when the soil slope after quarrying is higher than the value of the shear angle of the vegetative terrain: grating consists of a wooden grating nailed to the slope, filled with inert materials and vegetative terrain;
- gabionades, that consist of one or more series of parallelepiped elements (gabions) made of a double twisted metallic net, filled with coarse material and live plants;
- live fascines, which is realised through a pile of wooden stakes filled with inert materials and vegetative terrain;
- reinforced lands, that are realised putting geo-textiles and metallic nets in filling material (Bowles, 1991).

Cut and fill works are necessary to level the quarry face characterised by irregular slope. At this aim a deep analysis of the site is necessary and as result a detailed map of levelling has to be obtained. In a preliminary scheme the surface water flows need to be represented by means of arrows in order to indicate the direction of the flows. The drainage of superficial waters is in fact one of the main targets of levelling. The other factors that need to be controlled are the existing vegetation, the possible erosion and the sliding of soil (Harris and Dines, 1988).

In the preliminary scheme it has to be taken into consideration also the heights of some of the points of the surface to level in order to model the preliminary outline. The balance between materials coming from cut and fill has to be undertaken. The final levelling project has to include the final outline of the paths, the directional or slope variation, the heights of all the critical points, the drawing of the proposed outlines and the map of the area, the amount of materials involved in cut and fill works.

Drainage systems

Drainage system has to be previewed in order to obtain the minimum impact of the drainage outside the site to be reclaimed and to respect, as much as possible, the natural drainage of the site. Project parameters are determined by some natural conditions depending on climate, topography, soil status, geology, hydrology and vegetation that affect the surface run-off. On the other side also social factor, such as land use and population density have to be taken into consideration. Other
factors, that affect the project of the drainage system, are the bedrock depth and the water table level. Infiltration is higher where the bedrock and the water table level are deeper. Depending on the proximity to the source of the run-off, drainage techniques and devices can be different. Drainage channels and porous paving are usually used near the source of the run-off. Underground techniques are instead used to capture localised run-off. Vegetation allows to manage rain-run off in different ways either to facilitate infiltration or to slow down the superficial run-off (Harris and Dines, 1988).

Re-vegetation and functional devices

When projecting the re-vegetation of a quarry site, a phytosociological survey of the morpho-physiologic characteristics of the vegetal species is of primary importance to ensure durable results.

A special attention has to be given:
- to select the period for the plant settling, which varies for the different species,
- to adopt proper orientation, suitable support devices and right spacing between plants.

For sowing of lawns it is necessary to know the pedological characteristics of the soil.

The maintenance of the vegetation is obtained through a fixed irrigation plant.

For a social final destination it is important to realise functional devices that allow people to enjoy the restored place. Walking paths and paved surfaces need to be foreseen for people and service vehicles. Pavements can be of beaten earth, cobbled, macadam, grassy cart-road depending on aesthetics, users, climate, maintenance conditions and costs (Harris and Dines, 1988).

CASE HISTORY

The above-described methodology has been applied to an abandoned quarry, located in a site called Nuova Florida, near the town of Ardea, just in the south of Rome - Italy.

The target of the reclamation project was to realise a public park.

The landscape is basically hilly with low slopes. Only in correspondence of stony soils there are incisions with steep inclination. The territory presents a close hydrografical network. In the territory of Ardea the emerging geological formations come mainly from the explosive activity of a neighbouring volcanic area. The survey of the site highlighted stable slopes and absence of landslide-events.

The population of Ardea has rapidly increased soon after the world war II as shown in Table I.

The principal road system is represented by the Via Laurentina that get through the territory from north to south and links Rome to Ardea, and the via Ardeatina that is mainly charged by heavy traffic. The secondary road system of Nuova Florida, the site where the quarry is located, is characterised by roads with a geometric pattern (Figure 1).

Present status

The considered site used to be a lithoidal tuff quarry since 1936. The quarry was located in a isolated area surrounded by a oak-wood. At present, the quarry is located in the middle of a residential area (called Nuova Florida) and the wood has been reduced from 100 ha to 1 ha.

The site is hidden to the surrounding territory being located in a depressed position: it covers a surface of 50,700 m². Four zones can be distinguished:
- quarry floor: compacted soil with a horizontal extension of 27,000 m² and absence of vegetation;
- quarry face: a sub-vertical surface with a linear extension of 270 m and little shrubs;
- oaks wood: an horizontal area of 12,000 m², 12 m a.s.l. ;
- linking slope: an area with a 10% average incline between the wood and the quarry floor.

The little stream, passing through the quarry floor from north-east to west, has been used as sewage. It has been suggested to canalise the steam by means of underground piping.

The site has been recently fenced leaving three entrances: from east, from south and from the south-east side (close to the access to a neighbouring church).

In the abandoned quarry the vegetation is Mediterranean, composed mainly by evergreen trees and by shrubs and bushes that can live to hot and dry summers.

The most common trees are quercus ilex, quercus suber, pinus halepensis, pinus pinea, acer campestre and fraxinus angustifolia. The shrubs are phillyrea
angustifolia, erica arborea, mirtus communis, pistacia lentiscus, ginestia, donax and asparagus.

The climate indicators, as summarised in Table II, are favourable to vegetation growing.

Table I - Trend for inhabitants in the area (Ardea Municipality).

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhabitants</td>
<td>2,163</td>
<td>3,815</td>
<td>6,197</td>
<td>10,175</td>
<td>16,854</td>
<td>27,668</td>
</tr>
</tbody>
</table>

Table II - Climate indicators.

<table>
<thead>
<tr>
<th>Average raining</th>
<th>Average max. temperature (February)</th>
</tr>
</thead>
<tbody>
<tr>
<td>831 mm</td>
<td>26 + 29 °C - 0.9 °C</td>
</tr>
</tbody>
</table>

**Re-use targets**

The high residential development of the district and the absence of green areas for a social destination suggest the recovery of the abandoned quarry as a recreational park.

This destination matches also with General Regulatory Plan for Ardea town planning (PRG).

The recreational park has to make up for the functions of the natural environment, therefore it becomes of primary importance to preview green equipment, places for games and sport, refreshment and resting areas. The park is also intended for social events, therefore it needs to be planned suitable areas for public performances. For the two kinds of objectives different catchments are foreseen:

- as for all the public parks, the potential users are the citizens of the nearby district who are about 3,000 in winter and become 15,000 in summer;

- as the restored site could become place for social events the potential users should come from the nearness seaside of Ardea and from the nearby towns: eleven events a year, with an average presence of 1,000 persons for event, can be assumed.

**RECLAMATION PROJECT**

The project had to take into consideration all the above-described steps in order to follow the reclamation of the area. The layout of the project is shown in Figure 2.

**Integration with the territory**

Some essential services have to be built, in order to integrate the new park in the urban texture. In the site taken into consideration the viability doesn’t need to be changed, but only some limitations for road direction have to be pointed out. New parking areas around the site are foreseen (following the suggestions of the plan adopted by municipality and after selecting new areas located at north and east of the quarry). In such a way a number of 274 parking for cars and 7 for coaches has been previewed. The roads close to the park are large enough to allow car parking for social events. Trees and shrubs are suggested to limit the view-impact of the infrastructures.

**Remodelling of the quarry face**

In order to achieve steadiness conditions after landscape restoration, the slope of the quarry face has to
be reduced through a cut at the edge and replacement at the base: it has to be adopted in particular to restore the central part of the quarry face, where two benches (4 m in height) have been created during the past works. On one side of the quarry face gabionades need to be adopted; on the opposite side the link of the edge to the lower quarry surface has to be obtained even through the technique of vegetative covering. Techniques of Naturalistic Engineering, such as hydro-seeding seeding and live grating, have to be used to restore the vegetation on the new slopes.

**Land restoration**

![Figure 3 - Cut and fill program.](image1)

![Figure 4 - Section A-A' from Figure 3 (out of scale).](image2)

Table III - Terrain handling for land modelling.

<table>
<thead>
<tr>
<th>Cut</th>
<th>Fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>n.</td>
<td>Surface</td>
</tr>
<tr>
<td>[m²]</td>
<td>[m]</td>
</tr>
<tr>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>1,146</td>
</tr>
<tr>
<td>3</td>
<td>415</td>
</tr>
<tr>
<td>4</td>
<td>675</td>
</tr>
<tr>
<td>5</td>
<td>804</td>
</tr>
<tr>
<td>6</td>
<td>276</td>
</tr>
<tr>
<td>7</td>
<td>53</td>
</tr>
<tr>
<td>8</td>
<td>45</td>
</tr>
</tbody>
</table>

**Optimum path slopes and levelling of resting areas**

Optimum path slopes and levelling of resting areas have to be obtained by rock carrying as a consequence of cut and fill actions. The volumes coming from cut and fill are shown in Table III and in Figures 3 and 4. Trees or shrubs of big dimensions have to be not displaced even if there could be problems for levelling.

**Local hydrology setting and run-off drainage**

To prevent flooding of the quarry floor during intense rain periods, underground drainage is previewed in order to catch the meteoric waters infiltrated into the soil (Figure 5). Perforated PVC pipes are suggested.

For superficial run-off, drainage channels are planned.

![Figure 5 - Soil drainage.](image3)

**Sowing and plant settling**

Lawns have to be regenerated adding to the existing grass species (preferably indigenous) with suitable characteristics. For the slopes, essences with roots, able to improve the slide resistance, have to be used. Vegetal barriers have to be created to hide the surrounding buildings from particular point of views (paths, resting areas, etc.). For the achievement of the objectives of social utilisation of the park, trees and shrubs have to be settled with different techniques such as cuttings, and transplanting with or without terrain. Trees of second and first size have be used to reach microclimate comfort, particularly shadows on paths and resting areas, and to create ecological niches.
Viability and functional devices

The internal viability is composed by a principal road that links the two main entrance to the different areas (play field, recreational area, services) and by a secondary paths that lead the users to particular points like, e.g., a witness point on the quarry face (Figures 6 and 7).

- a wooden shed covered with creepers to be used for exhibition;
- a suitable fixed structure for easy assembly of a stage for music, theatre and other performances; in this case the quarry face its-self has to be the background.

The absence of acoustic barriers around the stage doesn’t allow the formation of secondary sound waves, therefore during performances use of amplifiers is suggested. The orientation of the stage has to be in south west direction in order to take advantage of natural illumination.

Signs of two types have to be located:
- informative signs regarding history and vegetation of the site;
- behavioural signs.

Paths lightening has to be given by low-stem lamp. On the contrary for services, recreational areas and for play-fields high-stem lamp have to be used. To give emphasis to some natural elements (slopes and trees) special spot-lights are foreseen. Depending on the area, different kind of equipment have to be used:
- resting areas with tables and benches;
- a suitable fixed structure for easy assembly of a stage for music, theatre and other performances; in this case the quarry face its-self has to be the background.

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Signs of two types have to be located:
- informative signs regarding history and vegetation of the site;
- behavioural signs.

Maintenance and costs

Pruning and phytosanitary prevention together with cleaning are the primary actions of maintenance for this kind of parks.

Maintenance has to be scheduled also for technological equipments (drainage, irrigation, etc.).
The items of costs are from project development and realisation and from managerial inputs. In the Table IV the costs of realisation are listed.

Table IV – Site remediation costs.

<table>
<thead>
<tr>
<th>Works</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total (US$)</td>
</tr>
<tr>
<td>Land surveying</td>
<td>1,600</td>
</tr>
<tr>
<td>Modelling</td>
<td>41,400</td>
</tr>
<tr>
<td>Terrain handling</td>
<td>7,800</td>
</tr>
<tr>
<td>Drainage</td>
<td>18,000</td>
</tr>
<tr>
<td>Sowing</td>
<td>9,700</td>
</tr>
<tr>
<td>Devices</td>
<td>282,300</td>
</tr>
<tr>
<td>Tree settling</td>
<td>6,800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>367,600</strong></td>
</tr>
</tbody>
</table>

The managerial inputs come from ordinary maintenance (cleaning, pruning), from personnel of the park (playfield, exhibition area, parking). A part of the cost is related to the number of people enjoying the park.

**CONCLUSIONS**

Remediation of the site after quarrying has been carried out taking into consideration not only all the features of the site but also the geographical context and the inhabitants' needs.

Particular attention is appointed to the following items:

- remodelling of quarry face in order to assure steadiness conditions;
- conditioning of the soil slope in order to control the water flow and drainage;
- recognising of proper road infrastructures and services in order to connect the site with the surrounding territory and pointing out new targets for the site considering the local demand for recreational services;
- evaluation of the costs of the principal operations and of the maintenance after reclamtion.

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**REFERENCES**


