# Reclamation of Granite Stone Quarry – A Case Study in Jostan Granite Mine, Tehran, Iran

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## 1 INTRODUCTION

Reclamation is a process of returning disturbed mined lands to a desired use, which dose not necessarily lead to the reestablishment of the original-natural conditions. The reclamation lands should not only be attractive but also stable over the years and safe for the visitors. It could be achieved, if development of sustainable land reclamation is in the agreement with the function and usefulness for the future needs.

Taleghan, with 10700 inhabitants, stands at the middle of snowy mountains of Alborz 40 km of east of Ghazvin and 45 km north-west of Tehran, capital of Iran, with 1300 Sq. Km area. The average annual temperature is +9.5 (-11ºc to +27 ºc), average rainfall is about 500 mm. Shahrood river with length of 105 Km runs east to west of this area. Taleghan dam with 420 million cubic meter of capacity is under construction on this river. Upon completion, the dam would be a turning point at Taleghan. It will have an immense impaction development at this region and rapid urban expansion plan will be existed in near few years.

This paper aims to explain the planning process of reclamation of Jostan Granite mine, which is located at 6 Km North West of Taleghan. The Jostan quarry was planned for extraction of three types of black, grey and red Granite blocks for application as dimension stone in construction of a university which is going to build near the mine (approximately 4 km from the mine). Because of that, the reclamation and rehabilitation of the mine is planned by considering the needs of 2000 students that are going to study in the university. Using Analytical Hierarchy Process (AHP) leads to use the area as leisure site, with park, tracks for walk, biking, restaurant and parking lot.

It is necessary to create reclamation area with minimum cost for maintenance, but remain to give the best result. Beautiful villages of Taleghan, which located in 1400 to 2600 meter above the sea, various flora, very nice landscape and local archaeology, make this place a pleasant region for tehranian's communities. Consequently reclamation cost of Jostan Granite mine is well compensated by the production of added value resulting from the new land uses. Figure 1 shows the geographical location of mine.

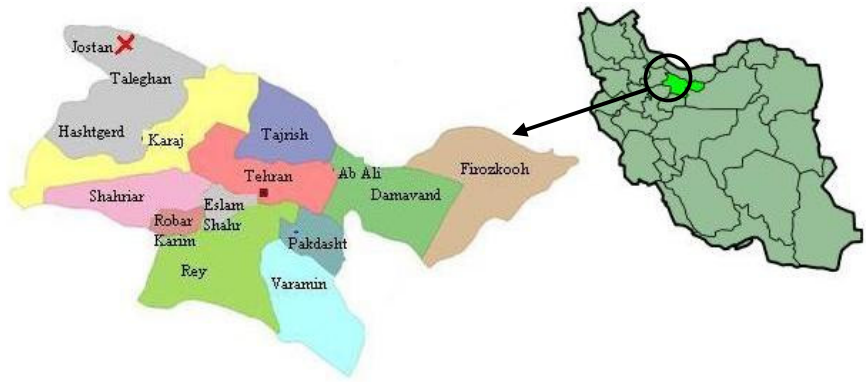


**Figure 1 Geographical location of Jostan mine in Taleghan**

## 2 OVERVIEW OF THE QUARRY AREA

The Jostan mine site located at latitude 36˚, 1Í and longitude 50˚, 55´, Northern Taleghan, 45 km north-west of Tehran, capital of Iran. The mine has been active since 2005 with extraction of isolated blocks of grey and red Granite and is planning to close in 2012. The area of the mine is 1.5 $Km^2$. Minable reserve is over 412000 cubic meters.

Although reclaiming mined property is usually the last thing mining companies will do at a site, but some advise to them be one of the first thing to think before beginning mining operation (Laurence 2006). By planning reclamation into the mining operation from the beginning, a company can reduce operating and overburden handling costs and increase property value. Therefore, planning mine with aspect of mine reclamation, will avoid potential problems (Stellin et al. 2005). For this purpose the geometrical parameters of the mine were defined. The bench height is 5 meters and for increase safety of reclamation plan the bench slope is 80 degree. A 3 meter bench wide makes revegetation possible. Whereas it was supposed to use the ramps as biking site, the wide of the ramps designed to be 8 meter. Figure 2 shows a preview of the final open pit arrangement. Figure 3 shows the actual state of the quarry.

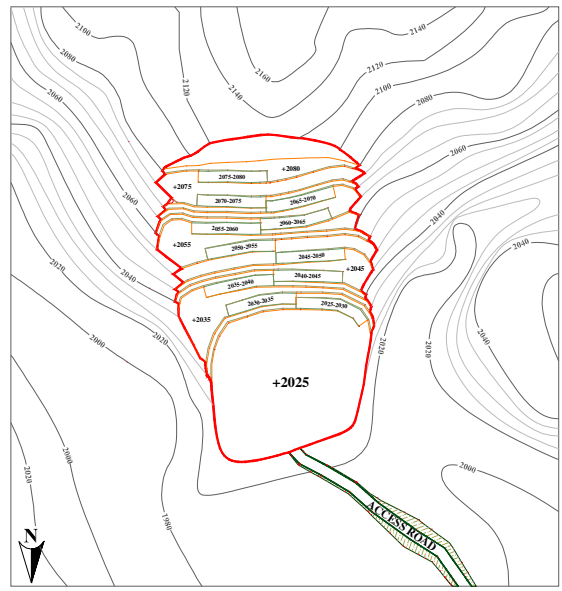


**Figure 2 final open pit arrangement of Jostan Granite mine.**

**Figure 3 actual state of the Jostan quarry.**

The ultimate pit limit after exhaustion of the quarry deposit was obtained by datamine software. The resulting excavation develops a new topographic relief with new and different creative possibilities for use. Figure 4 presents a 3D view of the mine site before and after mining.

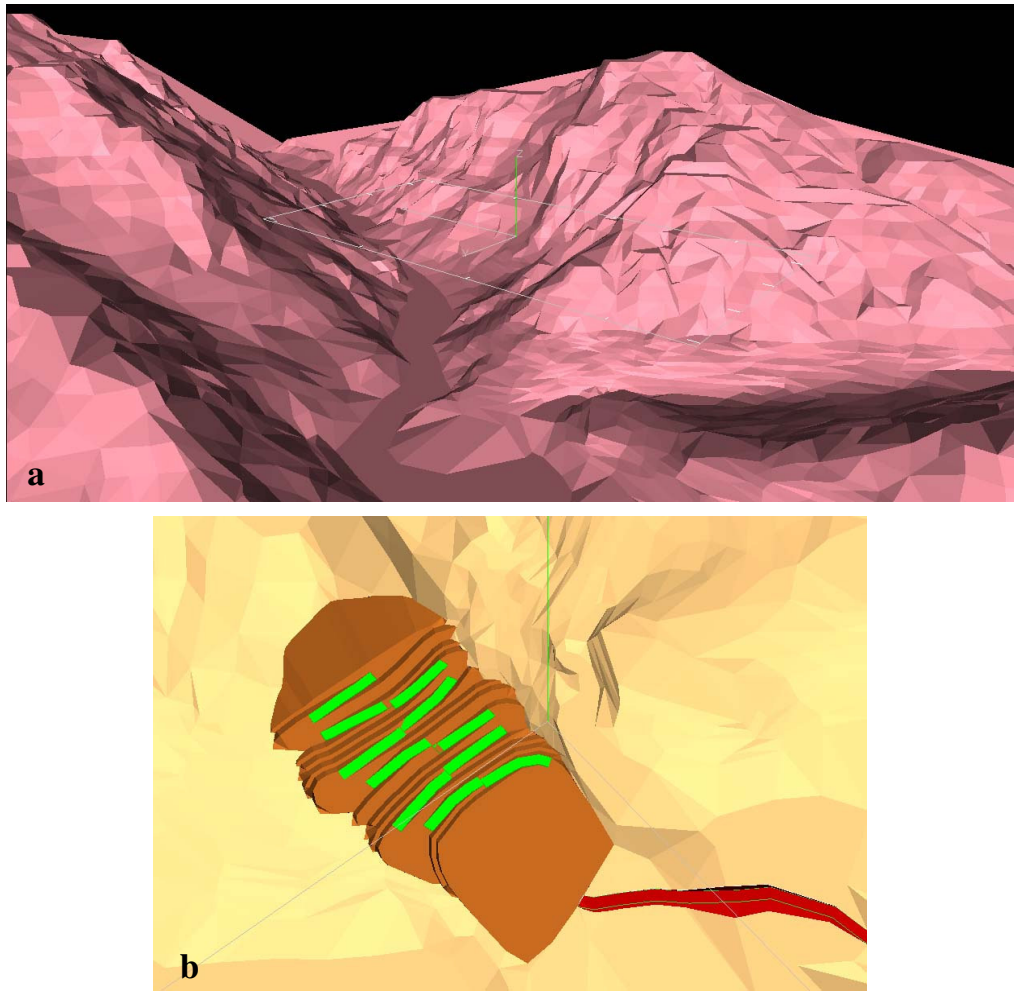


**Figure 4 3D view of the mine site; a) before mining; b)after mining**

# 3 RECLAMATION PLANNING

Surface mining adversely affects the living conditions, productivity, visual image and recreational values. The concept of "reclamation" combines all measures needed to make surface mined landscape productive and visually attractive again (Hester et al., 1994). The mined land must be reconstructed in such a way so as not to adversely impact the surrounding, unmined landscape and the disturbed ecosystem must be balanced again (Saxence et al., 2005).

This study included the five scenarios that were focused on the reclamation planning of the Jostan quarry, which are:

- To use mined land as agricultural purpose;
- To reshape the quarry and design an residential area;
- To use the area as a place for educational purpose;
- To revegetate the mined land with appropriate species for foresting and
- Using the area as a promenade site for tourists.

There are many factors that affect the reclamation planning of the mined site. These factors are both qualitative and quantitative. Decision-makers need a decision support system that evaluates the factors in a complex structure for optimal decision making. Analytical hierarchy process (AHP) is an appropriate method that can support decision-making, when examining various reclamation scenarios. First step in AHP trend is to demonstrate the hierarchy structuring of real complex problem which the general objective is positioned at the highest level (Saaty, 1990). In AHP technique the elements of each level compared to its related element in upper level inform of pair-wise comparison method. The results of these comparisons are shown in matrix form as below:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad \text{or} \quad A = [a_{ij}] \quad i, j = 1,2,...,n$$

Where:

aij is the priority of element i compared to element j. It must be noted that, in pair comparison of criterion if the priority of element i compared to element j is equal to $w_{ij}$ then the priority of element j compared to element i is equal to 1/wij. The priority of element compared to it is equal to one.

The importance of this approach is mainly used to calculate the criteria weights, since it has a no fuzzy set nature. After calculation of alternative weight compared to criterion weight and criterion compared to objective, overall priority of each alternative can be calculated

In spite of many advantages of the approach, only few applications of AHP model to mining industry problems have been reported in the literature (A. Bascetin, 2003). In this paper AHP approach applied to select the best scenario of reclamation of the Jostan quarry site. Therefore some measurements and observations were utilized in mine site and surrounding area of the mined land.

Shahrood river located at 9.5 km north-west of mine and supplies adequate water for farming. Chemical and physical properties of soil are completely appropriate for vegetation and fortunately mining activities does not affected the chemical properties of the soil. The removed overburden will use for reclamation and revegetation of the area. Soil density is 0.33 gr/cm$^3$ and less then two percent of the soil contain stone. The pH of soil is 7.76 and the percentage of $Co_3$, Ca, Mg, N and K is zero, 3.95, 0.87, 0.45 and 0.01 respectively.

Average of minimum, maximum and dew point temperature of Taleghan is 8.7 ºC, 21.4 ºC and 2.5 ºC respectively and average of wind speed is 4.4 knots. Average number of days with precipitation in 2005 was 76 days and monthly total of precipitation was 239.5 mm. Average of maximum relative humidity is 69 percent. Monthly total of sunshine hours is 2954.2 hour. Well growth of natural species in the mining area and in the Granite rock shows a favourable condition for planting (see figure 5).

**Figure 5 Growth of natural species between Granite rocks in the Jostan quarry mine**

The structure of the selection the optimum reclamation according to Saaty Hierarchy is given in figure 6. Criteria of each parameter are summarized in the picture. These criteria have been determined according to mine site properties such as micro and macro climate conditions, hydrology and hydrogeology, chemical and physical properties of soil, geological and geotechnical parameters and etc.

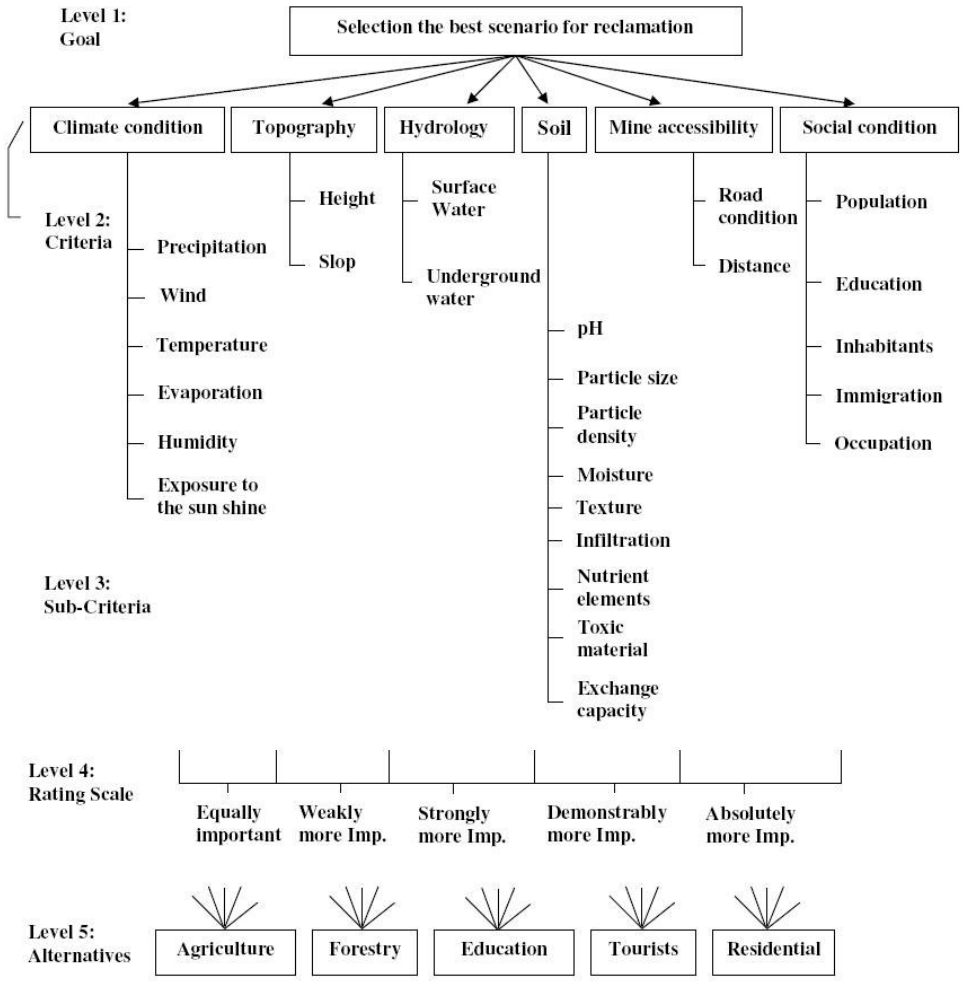


**Figure 6 AHP model for reclamation of Jostan Granite mine.**

Judgement scale used is given as: 1. equally important; 1.5 weakly more important; 2. strongly more important; 2.5 demonstrably more important, 3. absolutely more important (Fig. 6). There are two methods for synthesize derive results for decision, Distributive or Ideal. The Ideal mode assigns the full weight of each covering objective to the alternative that ranks highest under it. The other alternatives receive a weight in proportion to the highest alternative per covering objective. The Distributive mode distributes the weights of the objectives among the alternatives; thereby dividing the full objectives' weights into proportions relative to the percentage of preference of each of the alternatives

Table 1 presents the final results obtain by Expert Choice software and table 2 shows the Priority of each alternative with respect to criteria and sub-criteria. As seen in table the best alternative with the largest priority is tourist, so for reclamation planning it was decided to using the area as promenade site for tourists.

**Table 1 Synthesis summery with respect to selection the best reclamation**

| Alternative | Priority | |
|---|---|---|
| | Distributive mode | Ideal mode |
| Agriculture | 0.209 | 0.212 |
| Tourists | 0.236 | 0.230 |
| Forestry | 0.165 | 0.168 |
| Residential area | 0.186 | 0.186 |
| Education | 0.205 | 0.204 |
| Overall Inconsistency = 0.03 | | |

**Table 2 Priority of alternatives with respect to criteria**

| Criteria | Sub-criteria | Priority of each alternative | | | | |
|---|---|---|---|---|---|---|
| | | Agricultur | Education | Forestry | Residentia | Tourists |
| Climate condition | Precipitation | 0.014 | 0.004 | 0.012 | 0.005 | 0.004 |
| | Wind | 0.008 | 0.003 | 0.009 | 0.004 | 0.005 |
| | Humidity | 0.007 | 0.002 | 0.006 | 0.002 | 0.003 |
| | Temperature | 0.006 | 0.002 | 0.006 | 0.002 | 0.003 |
| Hydrology | Surface water | 0.027 | 0.010 | 0.021 | 0.015 | 0.010 |
| | Underground water | 0.006 | 0.004 | 0.009 | 0.007 | 0.003 |
| Mine accessibility | Road condition | 0.023 | 0.047 | 0.019 | 0.043 | 0.082 |
| | Distance | 0.007 | 0.014 | 0.006 | 0.019 | 0.026 |
| Social condition | Population | 0.005 | 0.014 | 0.003 | 0.012 | 0.008 |
| | Inhabitants | 0.003 | 0.008 | 0.003 | 0.011 | 0.006 |
| | Immigration | 0.008 | 0.20 | 0.005 | 0.012 | 0.018 |
| | Occupation | 0.023 | 0.45 | 0.011 | 0.015 | 0.037 |
| Soil | Texture | 0.002 | 0.001 | 0.002 | 0.001 | 0.001 |
| | pH | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 |
| | Nutrient materials | 0.004 | 0.001 | 0.003 | 0.001 | 0.001 |
| | Particle density | 0.002 | 0.001 | 0.002 | 0.001 | 0.001 |
| | Particle size | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 |
| | Moisture | 0.002 | 0.001 | 0.003 | 0.001 | 0.001 |
| | Infiltration | 0.003 | 0.001 | 0.003 | 0.001 | 0.001 |
| | Toxic materials | 0.004 | 0.003 | 0.003 | 0.004 | 0.003 |
| | Exchange capacity | 0.004 | 0.002 | 0.003 | 0.02 | 0.002 |
| topography | Height | 0.10 | 0.007 | 0.007 | 0.011 | 0.006 |
| | Slope | 0.034 | 0.013 | 0.026 | 0.015 | 0.014 |

# 3 LANDSCAPE DESIGN

Landscape design, means to prepare the relief to receive the vegetation, giving to it a steady and adjusted form for the future use of the ground or "making land useful again". In this way, the reclaimed surface mined site can again be incorporated into the total landscape structure in an ecological and productive way. For that purpose, specific structural planting forms are use (Dietrich, 1992). The final relief takes care the stability of slopes, the landscape and aesthetic erosion control and some other important aspects.

Results of AHP analyses lead to design the mined land as a leisure site. Social studies of Taleghan reveal that approximately 20 percent of population contains teenagers, but despite the significant percent, there is no playing area for them. As a result, reclamation and landscape was design base on providing a playing place including park, restaurant, biking track, roller- skating, parking and etc. Figure 7 shows the global recovery project suggested for quarry area after closure of the mining activities.

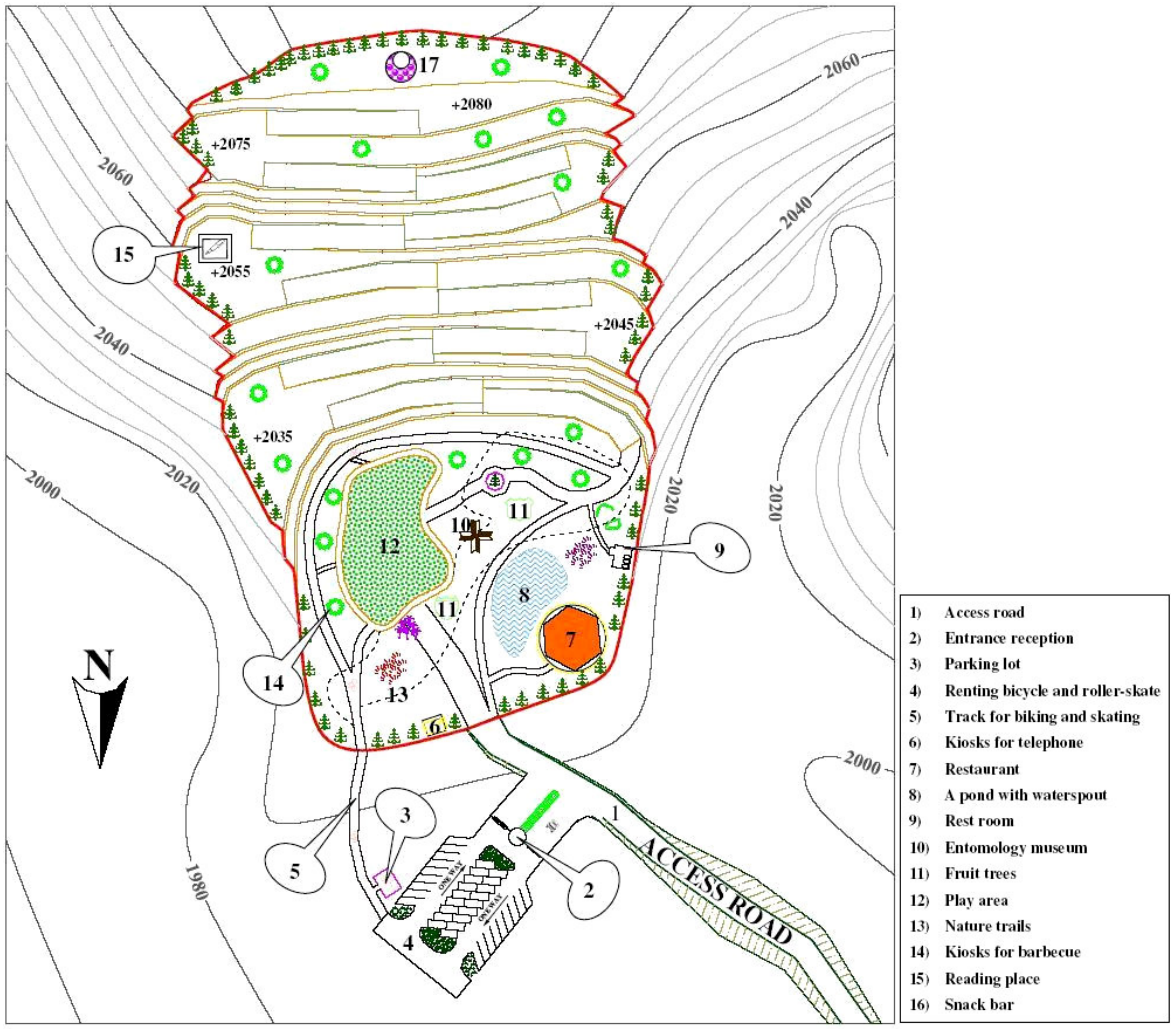


**Figure 7 Overview of area reclamation project after Jostan quarry closure.**

The access road is the road using for mining operation with 8 meter wide. The capacity of parking lot is approximately 40 cars. 2 meter tracks were placed all over the site, also around the play area, and access the mine ramps and benches which are designed for biking tracks. A snack bar is placed in the highest level of the mine for people who walk or bike up to there. A berm with 1.5 meter wide and one meter height is considered in ramps edges and will be vegetated with roses and shrubs to increase safety of biking track. A collection of various types of rare insects will be exhibited in entomology museum and will be very attractive for visitors.

Vegetation was planned with collection a rank of diverse plants that can apply to recover the area in the post mining stage. As indicated before, Taleghan has very good condition for vegetation, but the most common plants on the area are sour cherry and apple that choose as fruit trees on the land. For planting the surrounding area of mine, ever green trees such as pine combined with spruce, sumac and aspen selected. Combination of these trees will make a good view and spectacular sight-sing on different seasons. All kind of roses suggested for flower boxes. Creeper plants will cause different but nice view for the mine benches.

# 4 CONCLUTION

It is necessary to create reclamation area with minimum cost for maintenance and it can be achieved if construction works from the beginning are in line with agreed procedures and regular baces. Post mining use of Jostan Granite mine was discussed in this paper. Analytical hierarchy process (AHP) applied to select an optimum approach for reclamation of the quarry mine after closure and the mined land area was designed as a playing place including park, restaurant, biking and roller-skating track for children. The analytic hierarchy process that is studied in this paper is quite consistent, structured and intuitive. The main problem lies in the fact that since all comparisons are done by importance comparisons. It can be said that the recovery project and the reclamation of the mined area, has preview a lot of services designating it as a future recreational area.

Investigations on micro and macro climate condition, surface and underground water, chemical and physical properties of soil lead to choose sour cherry and apple as fruit trees. Because of special culture of Iranian which prefer to be in a closed site, ever green trees such as pine and cedar was choose as a barrier in surrounding area of the mine site. Colour of flowers, fruits and the loss of leafs during winter can be decisive for choosing the most adequate plants for the aspect of the area as a restoration region for the future park.

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