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## Impacts of Stone Quarrying and Crushing Activities in the Cluster Between Arkavathi and Vrishabhavathi River in Ramanagara District - A Case Study

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### Abstract

*The natural environmental factors including the rocky hill ranges have made several benefits. Mean while extraction of rocks through quarrying and crushing process have economical importance. This process is also a type of mining supplies' distinct type of construction materials with different categories and shapes. This chain of process releases a lot of harmful materials causing several negative effects on the surrounding environment, human life and activities, especially crushing units giving rise to the worst situation. These activities are concentrated in the district as several clusters. The present study as a cluster of sites lies between Arkavathi River in the west and Vrishabhavathi River in the east is very close to Ramadevara Betta vulture sanctuary. I can say this cluster is considered as core complex of stone quarries and crushing sites in the district. After my observation of quarry activates in the study area I can say with pain feeling 'the nature is looting' because the people here are scooping out the earth like those who have entered the tenacity to exploit quarry products mercilessly. The consequences of these activities, entire study area looking like barren land with unshaped landforms, dusty cover vegetation and people are suffering by various health issues and the livelihood activities becoming a standstill. In the meantime, gruff noise and microscopic rocky dust resulted dusty and noisy environment is the landmark here. The quarry activity created several huge hallows containing with radius of several meters and many feet depth without any fencing around it. These are impossible to landfills; they may lead to hazards if they leave them empty. Therefore, this research is an attempt to evaluate the effects of stone quarrying activities and suggest possible control measures to minimize the effects because this activity is required for development.*

**Keywords:** Stone quarrying; scooping; rocky cliffs; looting; gruff noise

### 1 Introduction

Present study is not conducted by experiments; it is based on my own experience

and experiment conducted by Sreenivasa and Ravana Reddy R.V under the title Socio- Economic and Environmental



Perception of Inhabitants of a Quarry Area-A Case Study of Bidadi. It is located very close to my study area but currently it is not running due to protest of local people with the influence of this article because of its significant effects on nearby settlements, temple<sup>(1)</sup>, and moreover the Ramadeverabetta vulture sanctuary located very close to it, which is the same distance from my study area too, along with my personal observations, interview with distinct levels of questionnaires like, residents, quarry workers and owners, compared with toposheets and satellite images. Comparatively, the study area is evident that has been modified which appears clearly in both tools; it is due to rapid development of quarry and crushing activities. The stones are used in various dimensions and distinct forms for various construction activities by supplying gravels, dust, M-Sand, slabs etc. Nowadays M-Sand is replacing the demand for river sand because of the strict sand policy and prohibition of sand extraction at river beds. Almost all physical environmental factors determine the life and activities of all living organisms on the earth's surface, together with the rocky hill ranges have made beautiful landscapes on the earth's surface, and play an important role in the formation of lithosphere. The elevated rock cliffs check the rain-bearing winds cause sufficient rainfall and provide shelter for wild animals, and grazing land for domestic livestock's (Images-1). Meanwhile extraction of rocks through quarrying and crushing process, regardless of economic benefits causes pollution and contaminations resulting in health hazards on both flora and fauna. Therefore, everyone should know the fact that "Life is more important than livelihood". So, this research paper tries to investigate the socio-economical importance and impacts on the environment as well as inhabitants around the quarry site. Complete stoppage of this activity is really impossible but there is a need for eco-friendly mining activity and environmental awareness.

## 2 Concept of the quarrying and crushing

Today both quarrying and crushing activities playing a vital role in the construction sector and have similar meaning for outlook but there is a slight difference of both activities.

Quarrying is primarily the mining of nonmetallic rock from shallow or open-pit mines to extract dimension stones like blocks, slabs, pebbles and etc. It is the process of removing rock, sand, gravel or other nonmetallic minerals from the ground in order to use them to produce materials for construction purposes.

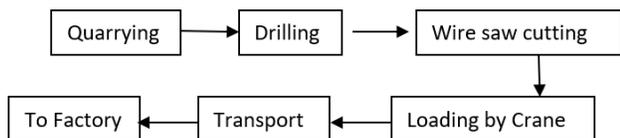


Fig. 1. Flow chart (1) of quarrying process

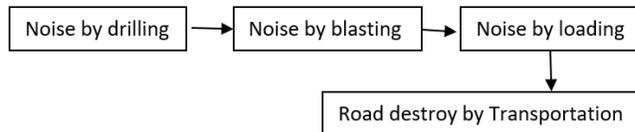


Fig. 2. Flow Chart (2) of Pollution

The stone crushing is defined as a mill or machine that reduces large rocks into smaller rocks, gravels, M-sand, rock dust etc. Crushing or grinding is used for various purposes.

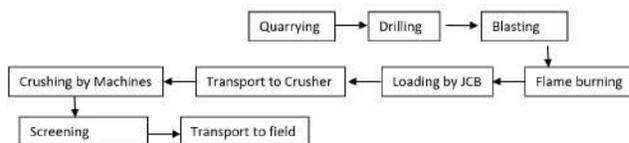


Fig. 3. Flow chart (3) of Crushing Process

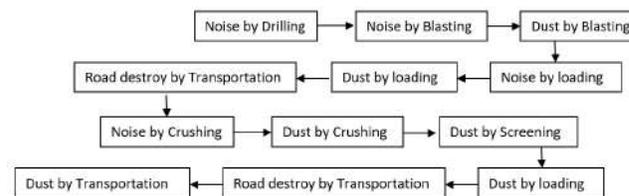


Fig. 4. Flow Chart (4) of Pollution

## 3 Statement of Problems

Recently frequent quarry incidents noticed in newspapers across Karnataka state is increasing day by day with illegal quarrying; deaths occur due to gelatin explosion, sliding, building cracks, overlapping of quarry dust, protesting to close quarry and crushing unit's etc. For example, Deccan Herald news dated, May 14, 2013 mentioned that the quarry units around Bidadi have witnessed formation of cracks in the walls of houses and temples due to explosions and crops are overlapped by rock dust is badly affecting living organisms and properties, encouraging the people to protest against the activities. In the same way Vijayavani news with the title 'Do not permit stone quarry activities' (Image 5).

Comparatively advanced type of stone extraction are unhealthy to environment compared to previous manual methods like use of hammer, chisel, flame burning which were less harmful to life and properties. But use of machines, explosives with chain of processes like drilling, blasting, crushing, transporting is very dusty and noisy which is the advanced method of extraction. This process deteriorates the gorgeous landscapes and causes several harmful effects on surroundings, to a large extent stone crushing process have a worst impact on both natural and built environment of



the surroundings. Besides these, the major focused problem is the current study cluster closely located to India's most endangered vulture species conservation sanctuary. Hence the present research has an enterprise to find consequences and possible suggestions to curtail the effects caused by the stone quarrying and crushing activities in the study area.

## 4 Research Questions

The present research subject was structured on the following questions;

- How does this activity affect the Vulture sanctuary?
- Do these activities badly affect human health and activities?
- Do these activities disturb the natural environmental factors?
- Are there any controlling measures to minimize any negative impacts?

## 5 Objectives

- To analyze the disadvantages of quarrying on elevated rocky cliffs which are known for significant habitats existence in the study area
- To analyze the issues of dusty and noisy environments.
- To assess the quarry workers and surrounding residents perceptions about these activities.
- To investigate the probable hazards and solutions resulting from stone quarrying and crushing activities at the natural and scenic landscapes.

## 6 Simplifications of objectives with my own perceptions based on previous literature related to the present topic

Present study area contains both built and natural factors like landscapes, drainage systems, fertile soil, natural vegetation, various fauna and flora species with settlements, agriculture, network of transportation as built environmental factors are undergoing deterioration by stone quarry and crushing activities. People of the surrounding residents and quarry workers of the cluster suffered a lot of issues caused by these activities.

The present study area incorporating several elevated rocky cliffs and rocky hill ranges has been checked the rain-bearing winds and causes sufficient rainfall, providing shelter for distinct wild species, provide grazing land for both domestic and wild animals, etc but the quarrying and crushing activities leads to vanishing of these significant natural gifts.

Basically the subsistence type of agriculture is predominant in the study area but unfortunately the yield and quality of the agricultural crops are very low due to crops perma-

nently overlapping by rock dust and people suffering different diseases due to tremendous noise by the activities.

## 7 Methodology

An attempt has been made to collect data from various secondary and primary sources to complete the above research objectives. The secondary data have been collected from diverse previous literatures like, journals, books, annual reports and websites etc.

- To establish an ideal scheme of research problem, the data have been accumulated from various secondary sources associated to research problems such as Google earth satellite images to identify the mining places, information from various relevant departments of government and NGO's.
- Further, primary data collected with use of GPS Map camera, interview method for residents, quarry workers and owners.
- Q-GIS tool used for mapping the study area and more vulnerable quarrying centers.
- Quantitative method like SPSS software applied for analyzing the data.

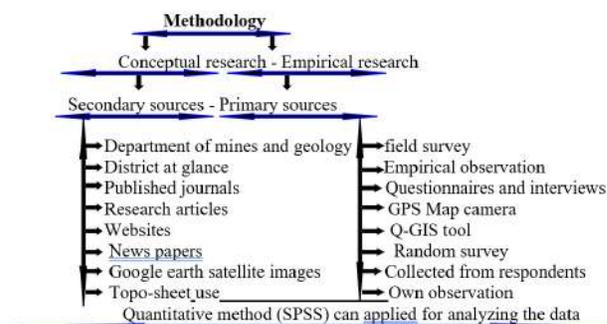


Fig. 5. Methods of study flowchart

## 8 Literature review

Without review of previous literature, construction of research process is very difficult and meaningless. Hence appraisals of various past literature are very essential for good research work because it is the synopsis data postulated by eminent researchers, scholars, authors, present research texts, journals, books, and dissertation work projects in various levels. To construct a noble research work I gathered various information from many international, national and regional level literature reviews.

Following are some objectives I found by reviewing good literature:

- It provides in-depth knowledge of the research methods related to the present study.



- It helps how to find the results and suggest measures to crack the issues.
- It supports finding the gaps of previous research and present research.

Following are some samples of literature reviewed during current research such as;

**Sreenivasa and R.V Ravana Reddy (2014)**<sup>(1)</sup>, found both positive and negative impacts with the help of survey in the study area and it caused altered socio-economic status of inhabitants, quarry workers, natural and built environment by stone quarry activities particularly within 1/3 km radius. And they suggest paying attention for resolving the issues with eco-friendly measures, because quarrying is economically viable and impossible to completely stop.

**Patil. J Swapnil, Supe .N Gajanan, Manatkar.A Pravin and Dr. Satish s. Deshmuk (2020)**, finds the consequences on groundwater quality and surroundings by quarry dust including both dissolved solids and suspended solids lead to reduce DO and exorbitant values of hardness and composite minerals.

**Javed Manzoor and Mahroof Khan (2020)** described the consequences of quarrying activities by field work and laboratory experimentation an acute negative results in terms of enormous dust, noise and water pollution, decrees in agricultural productivity, loss of local biodiversity, land degradation, generation of unproductive wastelands, deterioration in water quality, accidents, socio-economic conflicts and adamant health hazards to the people residing around the sites. No efforts are made by the local management of the units, functioning in the areas to minimize negative impacts on the environment and human health. The regulatory measures are urgently required to protect the environment and human health against different types of negative impacts arising from the activities.

**Barade V. D, Baviskar S.P, Dhende A.K and Durugwar Y.W (June 2023)**<sup>(2)</sup> through environmental impact of stone crusher quarry; A case study of Solapur district, Maharashtra observed during the study the large landslides and segregation of the loose soil, this may further lead to increased siltation rate in the catchments of Hipperga Lake.

**Naftal M.Moibi (oct 2007)**, in his research dissertation observed that the activities affect on soil erosion, water siltation, lose of vegetation and animals. They suggest that permission given to extract stones from quarries should be restricted by the government to create awareness among the people about the effects through media and officers. Besides these, governments should try to create more jobs to communities in other sectors which will reduce dependency on quarrying for their livelihood.

**Dr. Sandhya P. and Sneha Krishnan (2020)**<sup>(3)</sup> with a research article entitled Environmental and Health impact of quarry mining among quarry workers and residents by sample survey. The study reviles that 100 percent out of

all residents said that farmlands close to quarries do not support proper crops growth due to permanently overlapping of rock dust on both leaves and surface. The quarry activities should start with ecological and health concerns of the region. Today global concern is health and environment of global community have been established by several international protocols because of the emerging of environmental and health issues through achieving rapid economic development.

**Venkataramareddy B.V, Richerdson Lal and Nanjunda Rao K.S (Oct 2009)**<sup>(4)</sup>described with an experiment conducted for soil-cement technology that influences bed joint thickness and elastic properties of the soil-cement blocks and the mortar on the strength and behavior of soil-cement block masonry prisms.

**Venkataramareddy B.V and Hubli S. R (2002)**<sup>(5)</sup>in a research article, Properties of lime-stabilized steam-cured blocks for masonry that mixture of lime, clay and fly ash by steam cured blocks used for masonry construction is more strength as an alternative for use of sand.

**Babitha Rani H. and Shadakshara swamy N. (2018)** in the Journal of Industrial Pollution Control describe the response of leaves against rock dust is varied due to the level of openings known as stomata. This covers not only the photosynthetic surface but also interferes with the exchange of gasses and reduces the transpiration rate. The respirable particulate matter (RPM) produced by stone crushing process including crushing, screening and loading have become potential pollutants of stomata. Generally, the leaf tissue is in layers with a skin of epidermis layer on top and bottom and photosynthetic cells in between. The stomata are the entrances in the leaf bottom through which CO<sub>2</sub> enters to play its role in Photosynthesis. These openings are protected by a pair of specialized guard cells which open and close to allow gasses to enter or leave the leaf.

## 9 Significance of study

After evaluating several past literatures I found a clear picture that the majority of literatures' highlighted various impacts of quarries and related activities. But my present research focuses on landscape deterioration and its impacts on physical and built environmental factors.

- Present my research effort helps to find the reasons how quarrying and crushing activities lead to some issues even though these activities have economic importance.
- It helps to understand how physical landscapes are beneficial, but they have been brutally destroyed by quarrying activities.
- This research shows how cropping lands and natural vegetation are disturbed by the activities
- It also describes the methods of surface and groundwater contaminated by rock dust



## 10 Study area

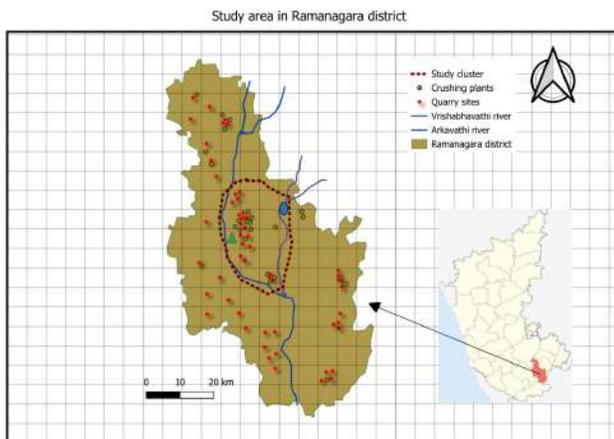


Fig. 6. Map generated by Q-gis software

### 10.1 Location & Extent

The study area is considered as a cluster of several stone quarry and crushing units, lies between Arkavathi River in the west and Vrishabhavathi River in the east is very close to Ramadevara Betta vulture sanctuary of Ramangarara district. This complex of quarry and crushing units extended in both ramanagara and Kanakapura taluks along Arkavathi river valley. It started in Hosadoddi quarry in the north and Doddamuduvadi quarry in the south.

### 10.2 Topography of the study area

The study area has several tall granitic hills which are famous for many short rock climbs because the district is home to some of the world's oldest granite outcrops. This region is covered in scrub forest and home to threatened bird and animal species like Yellow throated Babul, Long-billed vultures and Sloth bears. Ramadevara betta vulture sanctuary is more popular reserve sanctuary in India similarly Handigundi Sloth Bear sanctuary too.

### 10.3 Geology of the study area

The close pet granite is the major geological features of this region formed in the proterozoic era. This belt of rocks extends in the north to south direction which younger potassic granites.

### 10.4 Drainage structure in study area

River Arkavathi is the major river of the district rises in Nandi hill in Chikkaballapur district and flows through Ramana-gara and Kanakapura with the distance of 34 kms and finally

Table 1. No of quarry and Crushing units in the study cluster

Quarry units	Crushing units	Total
23	13	36

(Sources-Documents of Mines and Geology, Ramanagara)

falls into river Cauvery at Sangama. This river has three major tributaries such as Kumudvathi, Vrishabhavathi and Suvarnamuki. Besides these very small rivers like Antharamuki, Devamuki also drained the district. Vrishabhavathi is a minor river a tributary of Arkavathi rises in two sources, one is at Big Bull Temple in Basavanagudi and another at Kadumalleswara in Malleshwaram of Bangalore and finally joins river Arkavathi at Doddamuduvadi.

### 10.5 Socio-Economical background

The study area is basically agricultural background with red and loamy soil suitable for cultivation of crops like, Malbury, Maize, Ragi, Dairy farming, Mango etc.



Fig. 7. Elevated rock cliffs before quarrying



Fig. 8. Elevated rock cliffs after quarrying



Fig. 9. Crushing units

## 11 Interpretation of problems

The main objective of this study is to analyze the major impacts of stone quarry and crushing process in the study area even though it has economic benefits.

**Table 2. Respondents Perceptions**

	Total %	Male %	Female %	Quarrying staff %	Non staff %	Educated %	Illiterates %
Negative impacts of Quarrying process	80	65	85	75	80	85	65
Effects on landscape observation	68	80	55	80	85	90	70
Soil & Vegetation degrade	70	76	65	68	78	80	55
Noise pollution observe	60	70	55	80	60	79	66
Air pollution observe	48	54	40	66	52	74	42
Water pollution observe	35	38	25	30	20	43	18
Effects on Vulture species	65	78	45	65	85	80	30
Rehabilitation and remedies observe	25	22	20	15	18	15	12



**Fig. 10. Huge hollows formed by quarrying without fencing**



**Fig. 11. Dusty crops**



**Fig. 12. Destroyed roads**



**Fig. 13. Cracks formed in the building walls**

The following table shows the consolidated information about the negative effects of stone quarrying and crushing activities around the Ramadevarabetta vulture sanctuary by a random survey of 100 people.

**11. 1 Impacts on Natural environment**

Majority of the respondents more than 80 % including adults, old, educated, illiterate both male and female respondents in the study area stated that the gorgeous landscapes are going to deteriorate and look ugly (Images-2) by the quarrying and crushing activities. If unless control these activities in the district, one fine day the elevated, beautiful landscape will disappear resulting in a scarcity of rainfall and valuable species. Physical, chemical and biological qualities of the soil declining by mixing or overlapping of rock dust, dumping of rock waste etc leads soil to become unproductive. Soil erosion and loss of fertility, due to the emitting of rock particles and removal of vegetation when cleaning of forest for quarry purposes.

**Table 3. Table shows the percentage of various types of respondent's response**

Percentage of opinion for landscape degradation				
Type of respondent	Agreed	Partially Agreed	Not Agreed	Neutral
Old age group	65	10	15	10
Adults	10	15	68	12
Educated	70	10	15	5
Illiterates	25	30	20	25
Male	60	20	15	5
Female	30	15	25	30
Average	43	16	26	15

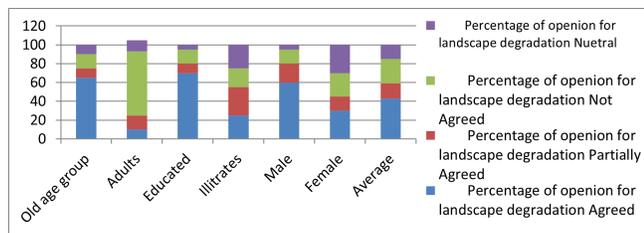


Chart 1: Graph shows the percentage of various types of respondent’s response

### 11.2 Impacts on Human Health and activities

Stone mining process causes noise pollution resulting in many Physiological and Psychological effects on man and other animals such as deafness, head each, stress, heart disease, chest pain etc. Dusty environment leads to cough, asthma, allergies etc.

Table 4.

Percentage of opinion for Health issues by the activities				
Type of health issues	Agreed	Partially Agreed	Not Agreed	Neutral
eyes	65	10	15	10
Lungs	10	15	68	12
Allergy	70	10	15	5
Respiratory	25	30	20	25
Average	60	20	15	5

Percentage of opinion for effects on human activities				
Effects on type of activities	Agreed	Partially Agreed	Not Agreed	Neutral
Agricultural crops	65	10	15	10
Effects on settlements	10	15	68	12
Effects on network of transportation	70	10	15	5
Average	60	20	15	5

Majority of the respondents in the study area stated that they are seriously suffering with noise and dust related problems (85%). Both psychological and physiological health issues suffered by nearby residents and quarry workers is very common. The noisy, dusty conditions within and around quarry and especially crushing centers leads to increased headache, cough, lungs problems, irritation, deafness, heart attack etc among the residents. Some work can be done with physical force. Such factors may expose quarry workers to an increased risk of hearing loss, respiratory diseases, muscular-skeletal injuries, asthma, chest pain, lungs issues etc.

### 11.3 Effects on Agriculture

Man can survive without luxurious things manufactured by economic development but impossible to live without food and other basic needs. Agriculture is the main source of food, cloth and other basic needs. Study area is predominantly an agricultural background growing varieties of crops like Mango, Ragi, Jower, Paddy, Sugarcane, Mulberry, maize etc. Animal husbandry is the major occupation and is the source of livelihood. But this primary human activity is suffering by rock dust overlapping on leafy crops (Images-5) resulting in reduced crop yield noticed in the agricultural lands present adjacent to quarry and crushing sites.

### 11.4 Effects on Settlements

Generally settlements are more concentrated near hilly ranges in the region because of easy availability of fodder for domestic animals, supply of woody materials, storing of rainwater in natural hallow along the valleys etc. But the quarrying activities can remarkably affect local fraternities leading to cracks formed in the walls (Images-7) of houses due to blasting in the quarries etc.

### 11.5 Effects on network of Transportation

The roads are the major networks in the area containing both metalled and unmetalled roads but completely destroyed by these activities due to restless tipper trucks and tractors transporting rock materials (Images-6).

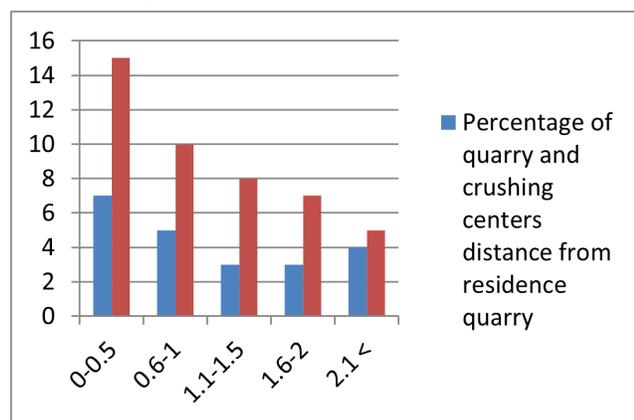
Table 5.

No of quarry and crushing centers distance from residence		
Distance from the residence (Km)	quarry	Crusher
0-0.5	10	7
0.6-1	6	3
1.1-1.5	2	2
1.6-2	3	1
2.1 <	2	0

The result found with above analysis, the distance of quarries and crushers is short became more seviour issues on health and activities of residents but if the distance increases the impacts on life and activities of human being is little less but affects on agricultural crops and road networks are more hazardous. Unfortunately the study area have more number of quarry and crushing centers lies nearest to the residence with less than 0.5 km to 1.0 kms hence the issues on health and human activities are immeasurable. Therefore, the distance is either more or less the harmful effects are very common, therefore this research is an attempt to evaluate the effects by stone quarrying activities to suggest possible control measures to minimize the effects in the study area because this



activity is required for development.



## 12 Limitations

The study does not conduct lab experiments for the problems.

The study is confined only to the field visit data.

This study covers very small area as a cluster.

## 13 Conclusion and Possible solution

Generally the quarry and crushing activities should be located far away from the residences mandatory according to Karnataka minor mineral concession rules 1994[2016 amendment]. But majority of the activities going on near the residences cause many issues particularly crushing centers disturbing more due to them being located more closely to the residences. After study of I various information on this topic it is little difficult to conclude whether the stone quarrying process is harmful or encourages economical development. But one can conclude from my personal observations and people's perceptions of quarry process, that it may be a very dangerous threat to landscapes, other living organisms, human life and activities, unless eco-friendly mining activity and environmental awareness. Particularly the landforms determine the impacts on slope, drainage, soil, vegetation natural scenic beauty etc of the region based on their elevations. But these landscape morphology fabricated by quarrying activities changes the visibility of their qualities. After the study of all quarry sites in the study area it is concluded that majority of the quarry sites changed into huge hallows by carving with the depth out of limit. The beautiful natural sceneries are structured by elevated rocky cliffs are deteriorating by looting these without mercy leads to changes

of landscapes.

**Suggestion 1:** It is impossible to landfill in such huge hallows so fencing must be built around hallows with caution boards to avoid disaster (Images-4).

**Suggestion 2:** The rock materials are necessarily required for the construction activities, but the chain of process involves many issues. Instead of using rock materials only if there are no alternatives with use of Hammers, Chisels and minor dynamites like fill charcoal plus sulfur and salt for blasting will reduce issues.

**Suggestion 3:** Recently tremendous use of hallow bricks manufactured with the use of rock dust for building construction due to cheap availability results in reducing the strength and very soon they will fall down causing hazards. If this happens in large scale, one fine day entire earth surface will be covered by rock dust and cement debris. Instead of using rock dust for making bricks, mud bricks with burning are more durable and strong than hollow bricks. If a building collapses, ultimately the earth's surface covered by soil is beneficial to living organisms. The mud slurry is prepared by ripening (Mortaring) of mud used for manufacturing mud bricks and building construction up to one or two floors. This will reduce more use of rock materials like M-Sand, dust, hallow bricks etc. This method will prevent more extraction of rocky structure and also it is eco-friendly with long durability.

**Suggestion-4:** The crusher units should be covered by green nets.

## References

- 1) Sreenivasa, V RRR. Socio-Economic and Environmental Perception of Inhabitants of a Quarry Area -A Case Study of Bidadi, Bangalore Rural District. *International Journal of Engineering Science Invention*. 2014;3(4):11-22. Available from: [https://www.ijesi.org/papers/Vol\(3\)4/Version-4/B0344011022.pdf](https://www.ijesi.org/papers/Vol(3)4/Version-4/B0344011022.pdf).
- 2) Barade V, Baviskar S, Dhende A, Durugwar Y. Environmental impact of stone crusher quarry; A case study of Solapur district. *Aarhat Multidisciplinary International Education Research Journal*. 2023;7(2):270-279. Available from: <https://zenodo.org/records/6942141>.
- 3) P S, Krishnan S. Environmental and Health impact of Quarry mining among Quarry workers and Residents: Evidence from Sample Survey. *International Journal of Advanced Multidisciplinary Research*. 2020;7(5). Available from: <https://ijarm.com/pdfcopy/2020/may2020/ijarm2.pdf>.
- 4) V VB, Lal R, Rao KSN. Strength and behavior of soil-cement block masonry prisms. *Journal of Materials in Civil Engineering*. 2009.
- 5) Venkataramareddy B, Hubli S. Properties of lime stabilized steam-cured blocks for masonry. *Materials and Structures/materiaux et constructions*. 2002;35(2002):293-300. Available from: <https://link.springer.com/article/10.1007/BF02482135#:~:text=Clay%2Dfly%20ash%20fractions%20of,for%20stable%20long%2Dterm%20strength>.

