International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 12 | Dec 2022 www.irjet.net p-ISSN: 2395-0072

ENHANCING EXTRACTION LIMIT IN OPEN PIT MARBLE MINE- A CASE STUDY

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Abstract – *Technical evidence has been presented in order to increase the ultimate pit angle of an open pit marble mines from 45 degrees to further 75 degrees in order to enhance the extraction limit of the mines. Which will boost the production of the mine. Flac slope software has been used in order to calculate the factor of safety of the ultimate pit slope so that the ultimate pit angle can be increased from 45 degrees to further 75 degrees in an open pit marble mines.*

Key Words: **Marble Mining, Flac Slope, Extraction Limit etc.**

1. INTRODUCTION

The aim of the study is to provide technical evidence against present legislation regarding open-pit mine working. We aim to increase the ultimate pit angle in small and medium open-pit mines in order to boost production and overcome a patriarchal problem. Analysis of the core samples by calculating the geo-mechanical properties, will help to calculate factor of safety of the slope thereby we can trim the bench even further increasing the overall pit width. The study will help to push the mineral production in small and medium size open-pit mines as the lease boundary is extreme limit of working. More mineral can be recovered which was earlier considered as irrecoverable due to restrictions in working.

1.1 About Study Area

The study area selected for the field experiments is Arora's J.K. Natural Marble Ltd, Morwad, Rajsamand, Rajasthan, India.The area is approachable by a tar road near NH-8 Udaipur-Ajmer route at about 78 km from Udaipur the nearest railway station is Kankroli at about 18 km from the mining area. The nearest airport is Dabok, Udaipur, Rajasthan which is at about 113 km from the mining area. The area has rocky & hilly terrain. The general strike direction of the rocks formation is NW-SE with dipping due western dips. Highest elevation is of 700mRL and lowest elevation being 682mRL in the area. The regional drainage pattern of the area is almost in SW direction. Area is characterized by low rounded excessively stony smooth rolling and deeply dissected country of banded gneissic complex with highly resistant strike ridges of marble and quartzite.

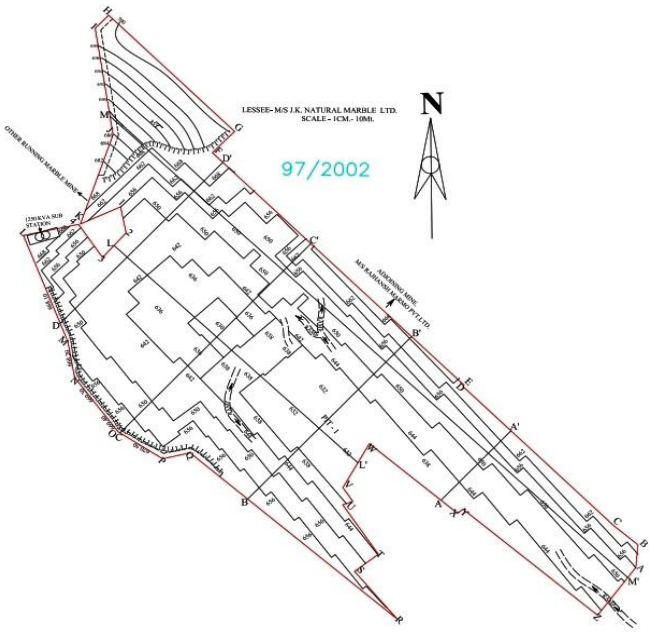

Fig -1: Working Plan

1.2 Rock Description

Weathered marble intermixed with amphibolites and hornblende schist is exposed on entire the surface area and within the pit jointed and fractured marble is exposed and some places good quality marble is exposed. It is white in colour and grain size is coarse grain. Some places marble is found intermixed with amphibolites rock. Calcite is dominant minerals having well developed twinning with sub-ordinate amount of muscovite, dolomite, quartz are also present as impurities.

1.3 Existing Method for Excavation

The mining in the lease area has been done by semi-mechanized mean by open pit method. Presently extraction of marble is done with drill machine; wire saw machine (for cutting of block) & crane (used for lifting of blocks). Dressing

machine does the dressing of block. Excavators & dumper are used to remove the fracture materials.

2. Geotechnical Investigations

Physcio-mechanical properties of the marble were evaluated which include compressive strength, angle of internal friction, dry density, cohesion.

Table -1: Physcio Mechanical Property of Marble

Physcio Mechanical Property of Marble	Value	Unit
Compressive Strength Measurement	117.28	MPa
Dry density	2872	kg/m^3
Angle of internal friction	75.81°	Degree
Cohesion	9.86	MPa

2.1 Rock quality designation

The RQD variation of rock at the mines have varied in the range 74 – 92%, 55 – 88% & 28 – 96%. It is observed that RQD is relatively low in the range of 20-45 in the upper region up to a depth of 30 m and is found to good beyond it. Accordingly, on an average the rock quality is described as mostly good to excellent beyond a depth of 25 m.

3.0 Structural Mapping of the Mine

Table -2: Dip direction

Slope	Dip Direction	Strike
A	133°	N36°E
B	222°	N52°E
C	193°	N13°E
D	148°	N34°E

Structural mapping of the mine has been done and slopes are demarcated in order to know the dip direction as in figure 2. The dip directions of the four slopes were evaluated with strike, table number 2.

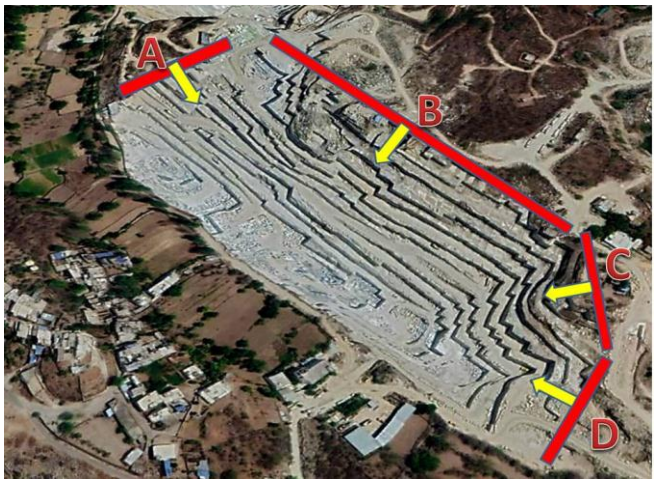

Fig -2: Structural Mapping of the Mine

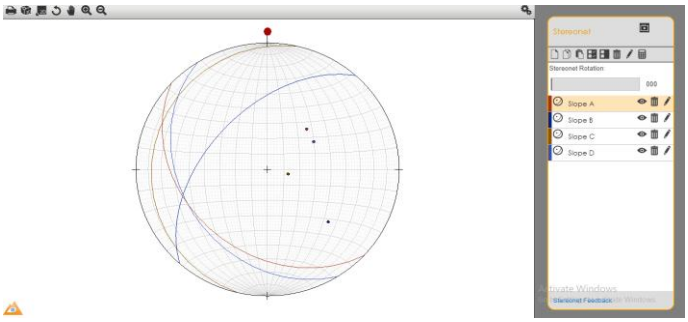

Fig -3: Stereographic Projection of the Joint plane in mine

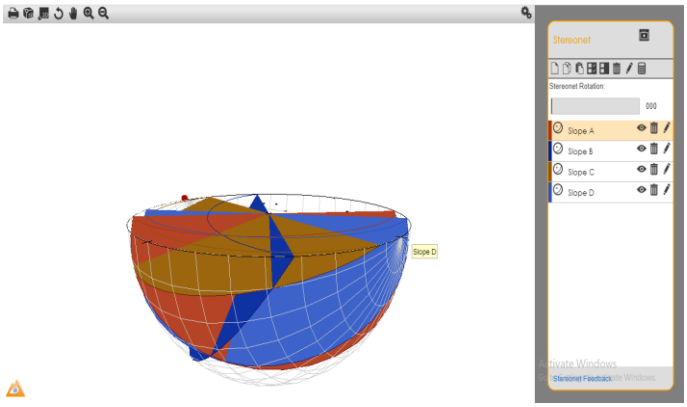

Fig -4: 3D Projection of the Joint Plane in Mine

4.0 Stability Analysis for Slope Design

Slope stability analysis was performed using FLAC slope which is a mini-version of FLAC which is designed specifically to evaluate factor of safety calculations for slope stability analysis. It is operated entirely from FLAC's graphical interface which provides rapid creation of models for rock slopes and solution of their stability condition. The factor of safety is basically defined as the ratio of resisting shear strength to the driving shear stress. The shear strength parameter viz. cohesion and angle of internal friction

obtained from the laboratory testing of rock core. By evaluating the factor of safety of slope we can suggest that the ultimate pit angle may be increased thus more mineral can be recovered without causing any serious harm to the mine environment.

4.1 Slope design for the mine

(i) Using Flac slope software a slope with an angle of 45˚ and height of 80 m was designed with the properties of marble having cohesion, angle of internal friction, dry density etc. The joints in the slope face are present at the two corners of the slope also there is no intrusion of water in the rock mass. The stresses were examined for coarse grain block using the software and it was found that the slope with the mineral like marble at an angle of 45˚ and with a height of 80m is completely stable. The factor of safety was 1.64 .

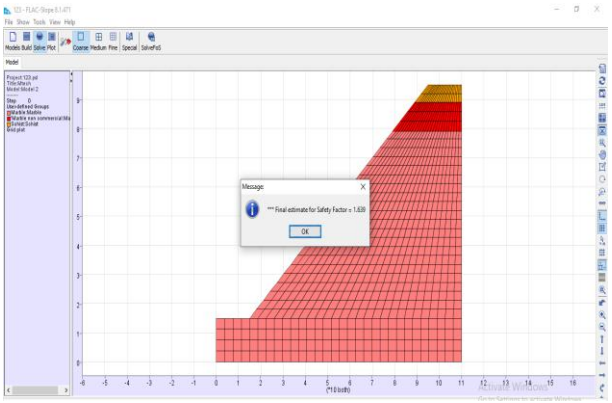

Fig -5: FOS Result at 45˚

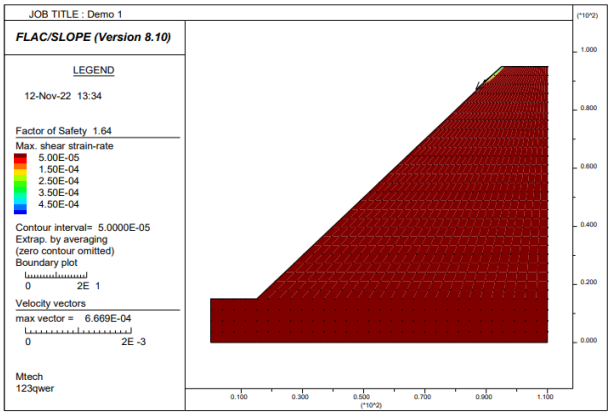

Fig -6: Projection Image at 45˚

(ii) In order to fulfill the aim to enhance the extraction limit we need to increase the ultimate pit angle, here a slope has been designed at an angle of 75˚ and the slope consist of minerals commercial grade marble. The factor of safety of the slope is 0.85

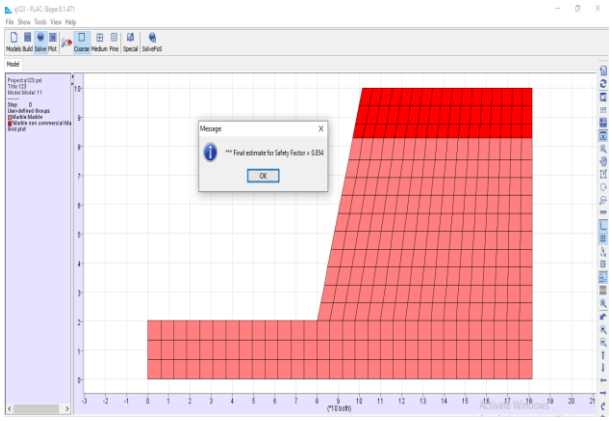

Fig -7: FOS Result at 75˚

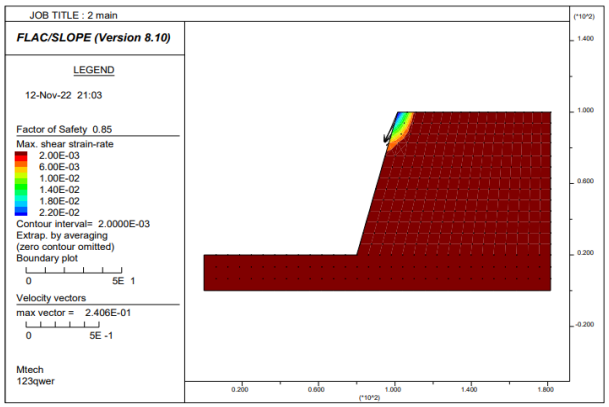

Fig -8: Projection Image at 75˚

(iii) Finally a slope was designed with an angle of 75˚ and an overall height of 80 m with bench height of 20 meters and bench width of 4 meters comprising marble as the mineral and eventually factor of safety of the slope was calculated which was found to be 1.518.

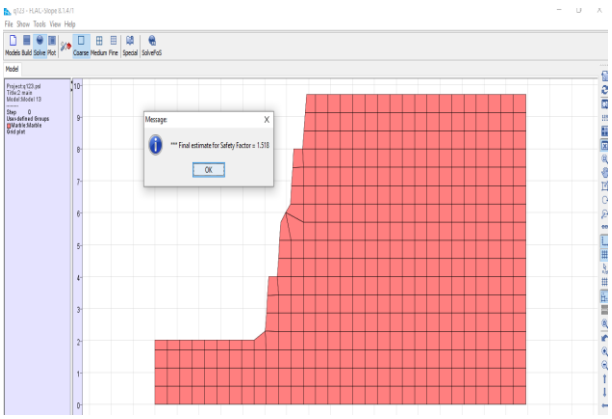

Fig -9: FOS Result at 75˚ with 80 m height

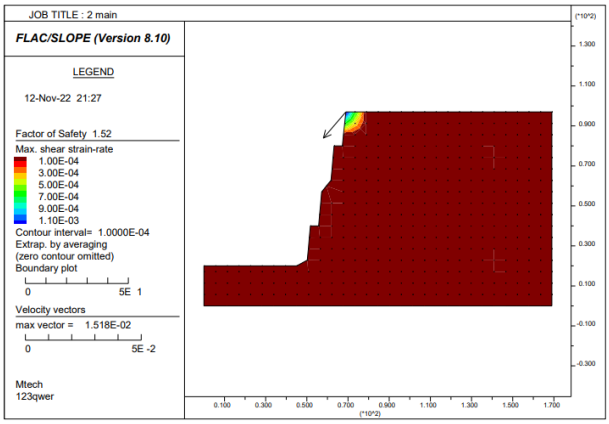

Fig -10: Projection Image at 75˚ with 80 m height

5.0 Simulation Result

In the present study slope at the North East side of the Arora's J.K. natural marble limited mines was selected in order to increase its angle from 45˚ to 75˚. The present study conducted at Arora's J.K. natural marble limited aims to enhance the extraction limit of an open pit marble mines. In order to increase the extraction limit we need to enhance the slope angle up to 75˚ in order to extract more valuable mineral from the earth crust. Laboratory and field experimentations results show that there is no hazard so as to increase the ultimate pit angle from 45˚to 75˚. The study also presents technical evidence against present legislature as in MMR 1961, Government of India, rule 106 Opencast mining which states that the sides shall be sloped at an angle of safety not exceeding 45 degrees from the horizontal, in order to increase the ultimate pit angle from 45˚ to further 75˚, slopes were designed both at 45˚ and 75˚ and factor of safety of the slope were evaluated.

5.1 Pit Slope Design

The ultimate pit slope design for the mines as suggested may be achieved during final mining operation by the progressive reduction of bench width as indicated. The width of intervening bench between overburden and marble should be maintained at a minimum of 4.5 m. The individual bench slope angle in overburden benches is to be maintained at around 85°. During the normal mining operation, it is however suggested that the bench height & width be maintained as per the statutory and the operational requirements. The existing bench height of 12 m may be maintained in the overburden rock mass. The final bench height in marble rocks may be maintained in the range of 20 – 30 m. However, the final bench height in marble will be limited to 20 m only with a corresponding minimum bench width of 3.5 m in that slope section, where waste rock intrusion is found in the marble rock.

We can see that there is no drastic change in the factor of safety of the slope design at two different angles, also the stability of the slope depends upon the height and width of the bench in cases if the intrusion or tension crack develops simultaneous adjustment in the bench height and bench width can be done in order to maintain the safety of the slope. In the final diagram, figure 10 bench height of 20 meters has been considered with the bench width of 4 meters and an overall slope height of 80 meters the bench height can also be increased up to 30 meters per bench and width can be increased to 4.5 meters per bench.

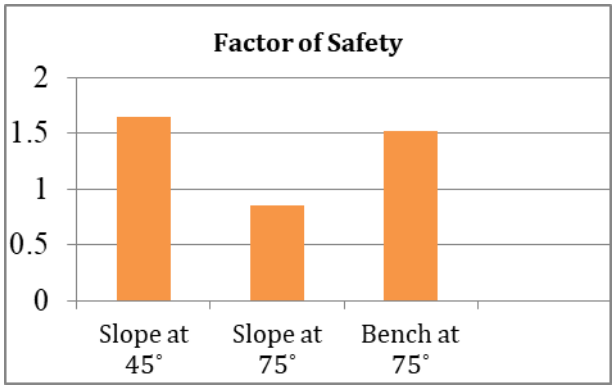

Fig -11: Comparison of Factor of safety

3. CONCLUSIONS

This study demonstrate that using Flac slope software we can easily calculate factor of safety of the slope which is very important in order to enhance the extraction limit of an open pit marble mine by increasing the ultimate pit angle of the mine.

Based on the field study and the research work carried out following conclusions and recommendations were drawn:

(i) Laboratory and field experimentations results show that the factor of safety of the slope designed at an angle of 45 ˚ for a mineral like marble was found to be 1.64 also the factor of safety of the slope design at an angle of 75 ˚ with a slope height of 80 meters was found to be 1.52. The above results show that we can increase the extraction limit in an open pit marble mine without any drastic change in factor of safety of the slope.

(ii) Recovery of the mineral can be increased by increasing the bench height from 12 m to 20 m and increasing the bench width from 3 m to 4 m for a slope height of 80 m, without compromising the safety of the bench. Thus production will be enhanced drastically keeping in mind the market demand and availability of minerals.

(iii) The study also presents technical evidence against present legislature as in MMR 1961, Government of India, rule 106 Opencast mining which states that

the sides shall be sloped at an angle of safety not exceeding 45 degree from the horizontal, in order to increase the ultimate pit angle from 45˚ to further 75˚, slopes were designed both at 45˚ and 75˚ and factor of safety of the slope were found to be sufficient in both cases, thus it can be easily inferred that the pit slope in case marble may be increased to 75˚.

ACKNOWLEDGEMENT

I would like to thank my Head of the Department and my guide Dr. Anupam Bhatnagar, for his valuable advice and technical assistance.

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