AJSTD Vol. 23 Issues 1&2 pp. 19-26 (2006)

QUARRY EVALUATION AND CONTROL OF BENCH BLASTING

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Received 01 August 2005

ABSTRACT

Potential sites of quarries were evaluated by numerical rating techniques. There are 3 groups of implied rating factors on the rock deposits in surveyed quarry sites: the resource characteristics, resource economics, and the optimal excavation. A final result for each potential site was recorded and compared. In case of ongoing quarries, the planning steps for bench blasting were also suggested. By using the written packed program, the output results can be automatically demonstrated. Further trial processes can be done and the optimized blast plan view is obtained.

Key words: Potential sites, Implied rating factors, Planning steps, Optimized blast plan.

1. INTRODUCTION

Three major types of rocks in Thailand have been used for construction purposes. They are Permian-Ordovician limestone, Cretaceous granite and Tertiary basalt. Potential resource sites and the ongoing quarries are located in various regions.

2. CONSTRUCTION ROCK PLAN

Following survey data, a long-term consumption prediction for crushed rocks was initiated [3]. The prediction methods are primary based on three principal data: the volume of market demand, the volume of rock reserve, and the production capacity of rock materials. Figure 1 illustrates the adapted graphs of rock prediction in the next 15 years.

The variations in prediction of the 2 lines indicated in Fig. 1 are due to one uses different minor input data. For the first rock prediction method, the consumption in the year 2000 is 132.2 million metric tons and in 2015 is 339.1 million tons. The consumption rate of the second graph prediction is generally lower than the first method. It is significant that the consumption trend of rock materials used in the construction industry is increasing sharply for the next 15 years. When one calculates the rate of consumption per person, Thailand has the rate of using rock materials in the year 2004 at 2.9 tons/person. This consumption rate is close to those of Canada and Germany but it is higher than Japan and South Korea.

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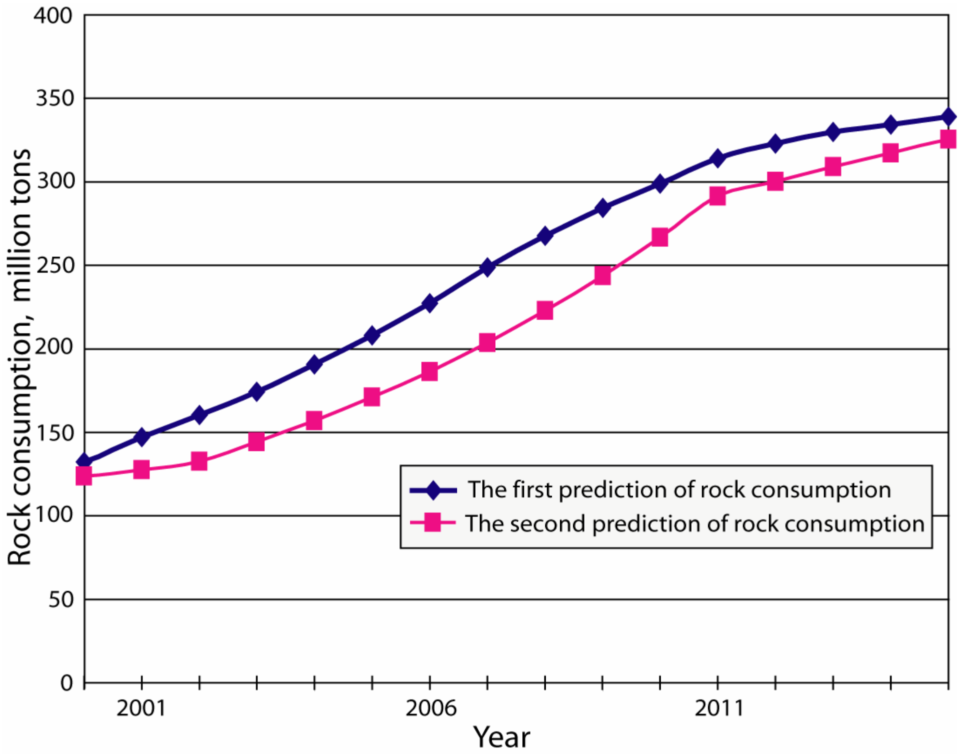


Fig. 1: *The two predicted graphs for rock consumption based on different methods*

Figure 2 shows the locations of rock deposit/quarry in which our research teams were carried out. There are 2 sizes of the ongoing quarries: the large and small size. A quarry defined as the large size when its production exceeds a limit of 200,000 cubic meters per month, otherwise it is the small size. All quarries of large sizes are limestone quarries and their fragments are mainly used as a raw product in the Portland cement industry.

3. ROCK DEPOSIT EVALUATION

In the process of numerical rating for rock deposit, there are 3 groups of site parameter that have to be evaluated. Descriptions on the involved parameters at the potential sites of quarry are:

3.1 Rock resource characteristics

The first group is the natural characteristics of rock in that deposit. Minor components that have to be evaluated in this group are based on the topography, general geology, land use, other agricultural and biogeographical impacts of the area, and reserve estimation.

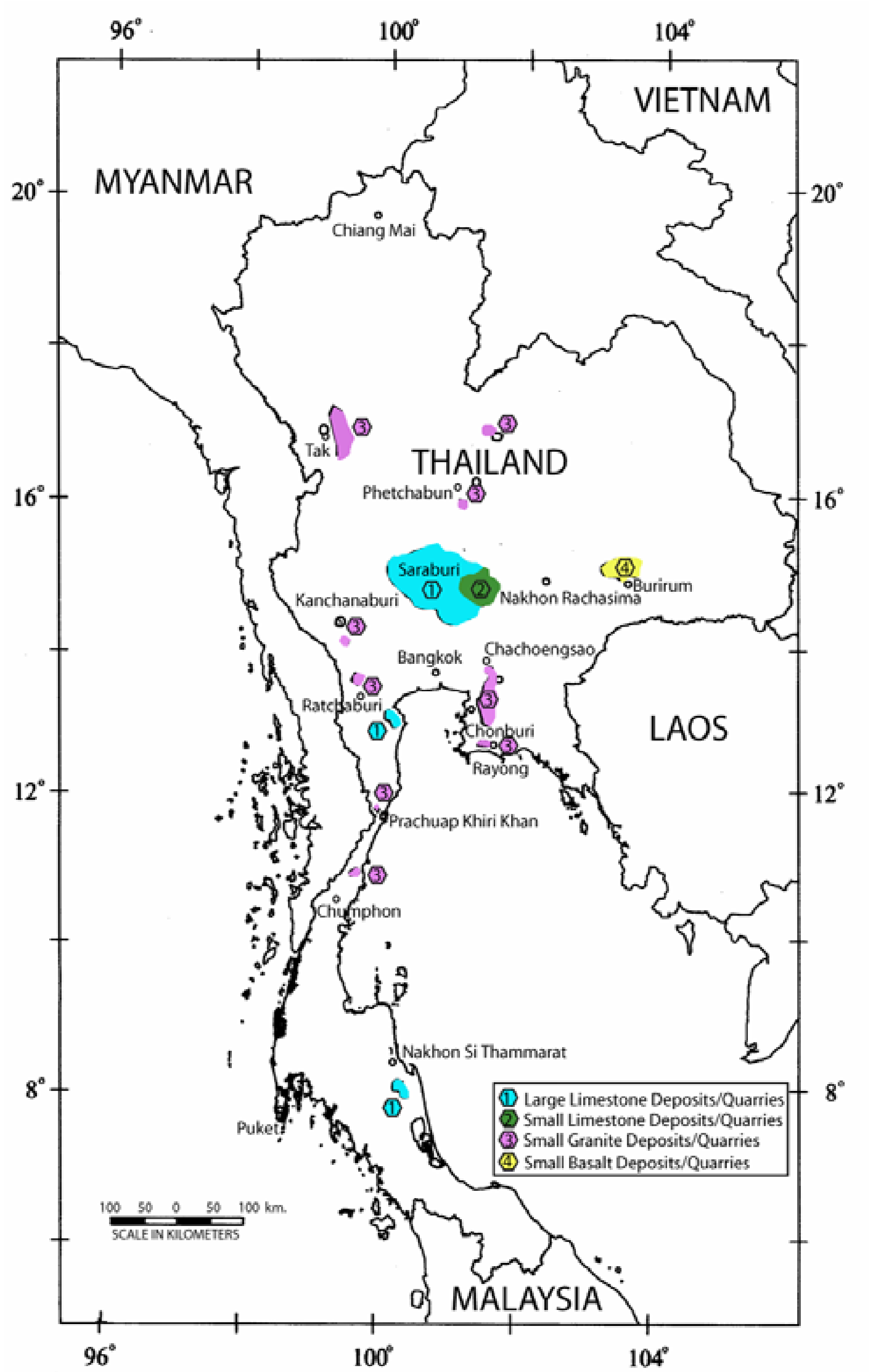


Fig. 2: *The location map for the rock deposits and the ongoing quarries*

Fig. 3: *An evaluated site of potential limestone quarry in the southern part of Thailand*

Table 1: *Designation values on 3 rating groups for a small size limestone deposit (Fig.3)*

Evaluated groups	Evaluated factors	Designation values
Group 1 Rock Resource Characteristics	Topography of the area	3
	General geology	3
	Land use	4
	Agrilcultural impacts	2
	Biogeographical impacts	2
	Reserve estimation	3
Group 2 Resource Economics	Rock resource quality	3
	Potential quarry location	3
	Potential crushing plant location	2
	Buy and sell market	3
	Suitability of site excavation	1
Group 3 The Optimal Development Method	Estimated overall costs	2
	The optimal design for development	2
	Reclamation and utilization	2
	Other specific developing factors	3
	The Final Result	38

3.2 Resource economics

The second group is the basic economic components of the site area. The included rating components in this group are rock reserve, quality of rock mass, appropriate potential sites of quarry and crushing plant, construction trend, current status of buy and sell market.

3.3 Optimal excavation

The third group is based on the excavation of in-situ rock material. The optimal method is dependent on the suitability of excavation, estimated overall costs, the optimal design for development, reclamation and utilization, and other specific factors.

Evaluation criteria are such that the designation values for minor components within each group are assigned between 1-4. The highest number for one specific component is 4 and the lowest number is given to be 1. Only the decimal point of 0.5 is allowed. An example of field rating for the potential site is shown in Table 1. The final numerical number of the site is obtained by summation of all assigned values. This final result is very useful in the selection process. Further assessment criteria are necessary before the surveyed site be accepted as an additional source of rock supply.

Advantage points of the numerical rating method are the method is quick, easy to use, and their rated values can be used as the data base of digital mapping. Potential areas of higher rating values can be shown on the map with one specific color to make the background different from other areas of lower rating values.

4. CONTROL OF BENCH BLASTING

The design of bench blasting to match on the impact regulations set by the Mining Technology Division - Ministry of Industry, is also one of involved research projects [9]. A written packed program used the Dephi compiler, was proposed [4, 7]. By using the input data of the trial quarry, the appropriate bench geometry and suggested explosive weights can be obtained. If the suitable pattern in bench blasting is determined, the optimized cost of excavation can be achieved for each geometric plan view of a particular design pattern.

An example is shown in Fig. 4 which their results obtained from the execution of packed program. The limestone quarry is located in the central part of Thailand and using the Ammonium Nitrate – Fuel Oil (AN-FO) as the blasting agent. There may be more than one suitable pattern of bench blasting. It is thus up to engineer to choose which pattern that it is most appropriate to that quarry face.

On the assessment of blast impacts, there are 3 stages of recommended impact regulations. These stages are the normal case, the awareness case, and the historic structure case. The normal case is to design explosive weights per delay according to the predicted graph (Fig. 5). On this graph, the modified trend line [1] is applied. The ground vibration prediction of field data and its permitted peak particle velocity is 0.025 m/s. This predicted graph was checked with the trial quarries and their results correlated well with other country standards.

For the awareness case of quarry blasting, the suggested values set that the distance between the community and quarry face is 500 m, or can be less than 500 m but not less than 150 m. The peak particle limit is 0.012 m/s with any kinds of blast frequency. A value of scaled distance for this case is 16 m/kg$^{1/2}$.

The extreme one is the historic structure case and it is set for the threshold limit of antique preservation structure. The distance from the historic structure to the blast source must be more than 150 m. A peak particle velocity must not exceed 0.004 m/s.

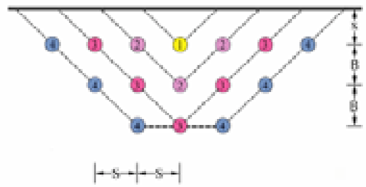
Calculation of quarry blast

Input variable data

Explosive diameter, mm	200
Bench height, m	20
Bench slope, degrees	75
Drill hole inclination, degrees	75
Number of rows	3 (Fixed)
Required rock volume, m^3	15,000
Powder factor, kg/m^3	0.45 – 0.55
Rock type	Limestone
Density of rock, kg/m^3	2,680
Explosive type	AN–FO
Density of explosive, kg/m^3	820
Maximum percent of error	10

Output results

V cut, progressive delay



Burden (B), m	5.5
First row burden (x), m	5.5
Spacing (S), m	7.5
Stemming (T), m	4.0
Sub–drilling (J), m	1.5
Number of holes	15
Total volume of rock, m^3	14,555
Total weight of explosive, kg	7,350
Powder factor, kg/m^3	0.50

Fig. 4: *The input data of bench blasting for the large limestone quarry and its output results*

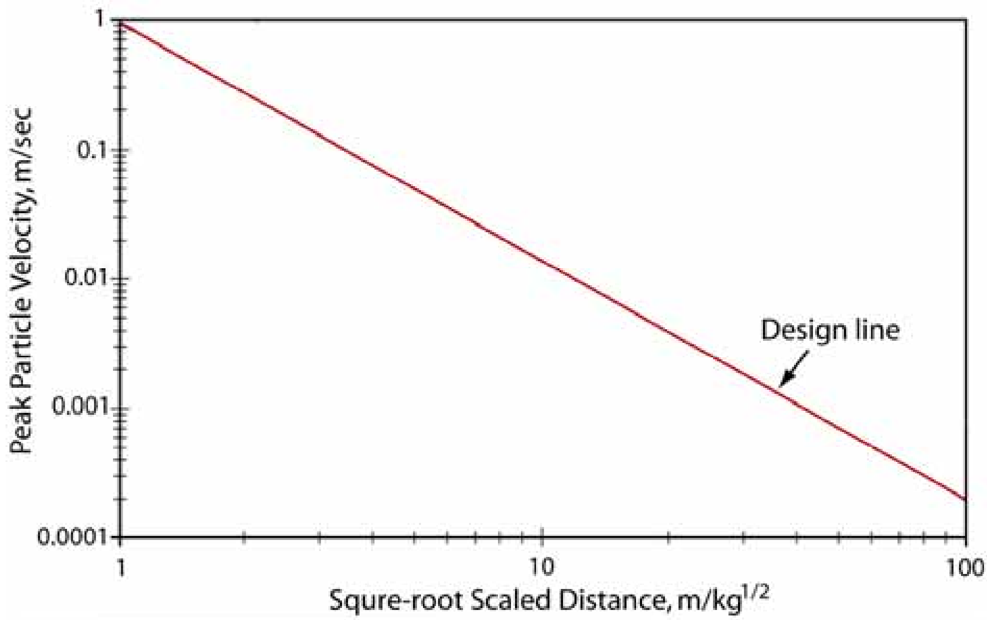


Fig. 5: *A recommended graph for the normal case of bench blasting to design the charge weights related to the safe distances*

5. DISCUSSION

On the review of reserve estimation, there are some provincial areas in Thailand that will be need additional souurces of rock supply for construction. Providing guidelines of the numerical rating techniques have helped to confirm the conclusion. In some areas, however, granite and basalt can be substituted for limestone. The unit cost of producing crushed rocks per ton for igneous rocks occurred near the construction site may be slightly higher than limestone. This unit cost has to be compared with the transportation cost for carrying limestone aggregate in the outer area to the construction site.

From geological maps of the northeastern part, sandstone is widely distributed in the area. Sandstone, however, has the disadvantage point on being easily broken along its bedding plane. It is not recommended to use sandstone as a major rock aggregate for construction purposes.

The back analysis results from blasting data of several large quarries are shown as graphical curves in Fig. 6. There seems to be a correlation between the fragment size of limestone and the weight of explosive (AN-FO), specified as powder factor. The range of powder factor values (P.F.) is 0.40 - 0.66 kg/m^3. The average fragment size, taken the values from observed field data at 80% passing, is 0.5 m (plus or minus 0.05 m).

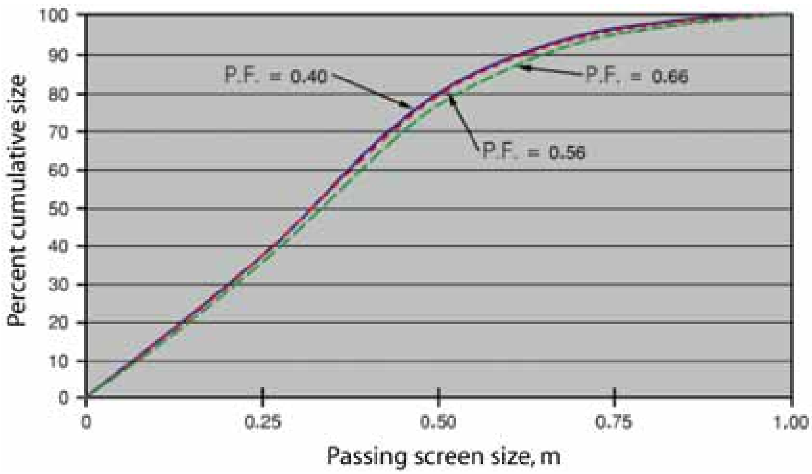


Fig. 6: *Comparison for the fragment sizes and the explosives used in bench blasting*

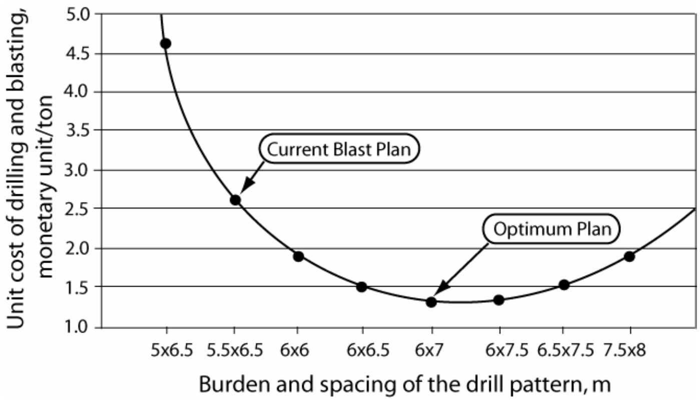


Fig. 7: *The trial plots for the optimization of drilling and blasting costs of a large limestone quarry*

In a specific quarry, the height of drill hole in the bench blasting is normally fixed due to the capacity of the drill machine. To optimize the costs of operation, the engineer can adjust or select the plan views. Figure 7 illustrates the trial plots of several plan views in one specific blast pattern. The lowest point of unit cost of drilling and blasting in the graph is the optimum plan.

6. CONCLUSION

An improvement on techniques of evaluation and optimization is the solution for better efficient planning. The evaluation technique offers greater flexibility in actual operations for a specific deposit site. Engineers should utilize the written program based on the field information and the measurement readings in bench blasting. The solution of the optimum plan view can have more than one option to choose, since it is dependent on topography, site geology, and other involved factors. The control of blast impacts is also one of the important regulations.

ACKNOWLEDGEMENTS

The financial sources from Chulalongkorn University and from the Mining Technology Division are highly appreciated. Thanks are due to our research team on their continuous works for several years. Generous permission of the authorized personnel to allow data to be published is acknowledged.

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