Planning and evaluation for quarries: case histories in Thailand

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Abstract: Numerical rating numbers were applied for evaluation of rock resources during the planning process. Implied rating factors for sites of potential quarries were resource characteristics, resource economics, and the optimal excavation. A final result for each rock deposit was recorded and compared. The controlled impacts during blast excavations were also suggested. Concluded remarks from case histories indicate that methods on the numerical rating and optimized blast impacts seem to have great benefits for quarry planning on both economic and environmental concerns.

Résumé: Les nombres déterminant numérique ont été appliqué pour évaluer des ressources en roche au cours de processus envisageable. Les facteurs décisif implicite pour lieux de la carrière potentiel ont été la caractéristique de ressource, l'économique de ressource et le creusement optimal. Le résultat final pour dépôt de chaque roche a été enregistre et compare. De tels carrières en marche, les impacts contrôlable pendant les creusements explosif ont également été propose. Les remarques concluant de cas en histoires indique que les méthodes des nombres déterminant et des impacts explosif optimum ont l'air de prendre des grand profits pour le carrière envisageable en ce qui concerne l'une économique et l'autre environnement.

Keywords: rock description, numerical model, blasting, case studies

INTRODUCTION

Three major types of crushed rocks have been used for construction purposes in Thailand. They are Permian-Ordovician limestone, Cretaceous granite and Tertiary basalt. Potential resource sites and the active quarries are located in various regions. The size of quarry is defined as large when its crushed rock production exceeds a limit of 200,000 cubic meters per month, otherwise it is classified as small size. Major large size quarries are in the central part, approximately 100 km north of Bangkok. All quarries of large size are limestone quarries and their outputs are mainly used as a raw product in the Portland cement industry.

MANAGEMENT PLAN FOR ROCK MATERIALS

For a developing country, a management plan of rock materials is essential. The plan for rock products used in the Thailand construction industry was drawn up by the Mining Technology Division and Chulalongkorn University (Tangchawal et al., 2000, Tangchawal, 2005). This plan was based on three principal types of data: the volume of market demand, the volume of rock reserve, and the production capacity of rock materials.

Following survey data, a long term prediction for crushed rock consumption was initiated. Figure 1 illustrates the predicted curves for rock consumption from the two methods used. Variables of consumption prediction are mainly on the predicted economic growth and the assumed weight factor for construction projects in the country. The consumption trend of rock materials used in the construction industry is increasing sharply for the next 15 years.

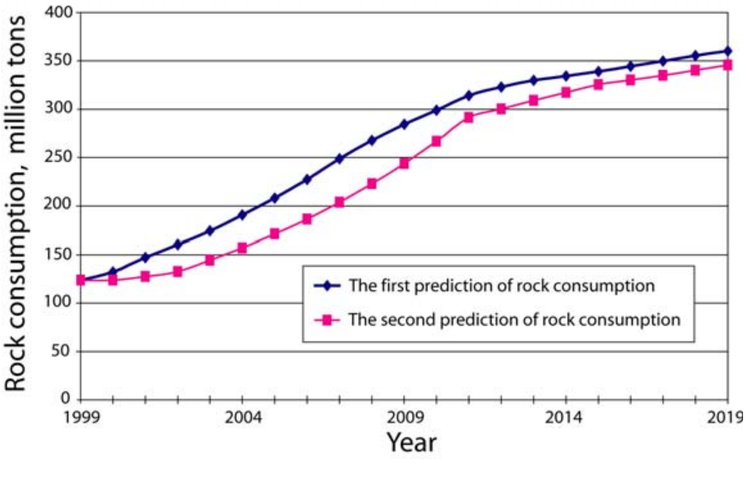

Figure 1. Two curves of predicted rock consumption from two different methods.

In Figure 1, two trend lines of predicted rock consumption are shown. The variations in predicted consumption of the 2 lines are due to the application of different input values. However, their variations are within acceptable limits. 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. But for the second method, the consumption rate is less than about 8 %.

From the predicted data, the population in Thailand for the year 2004 is 64.5 million. The average value of the rate of using rock materials per person in 2004 is 2.9 tons. This consumption value is close to those of Canada and Germany but it is higher than Japan and South Korea.

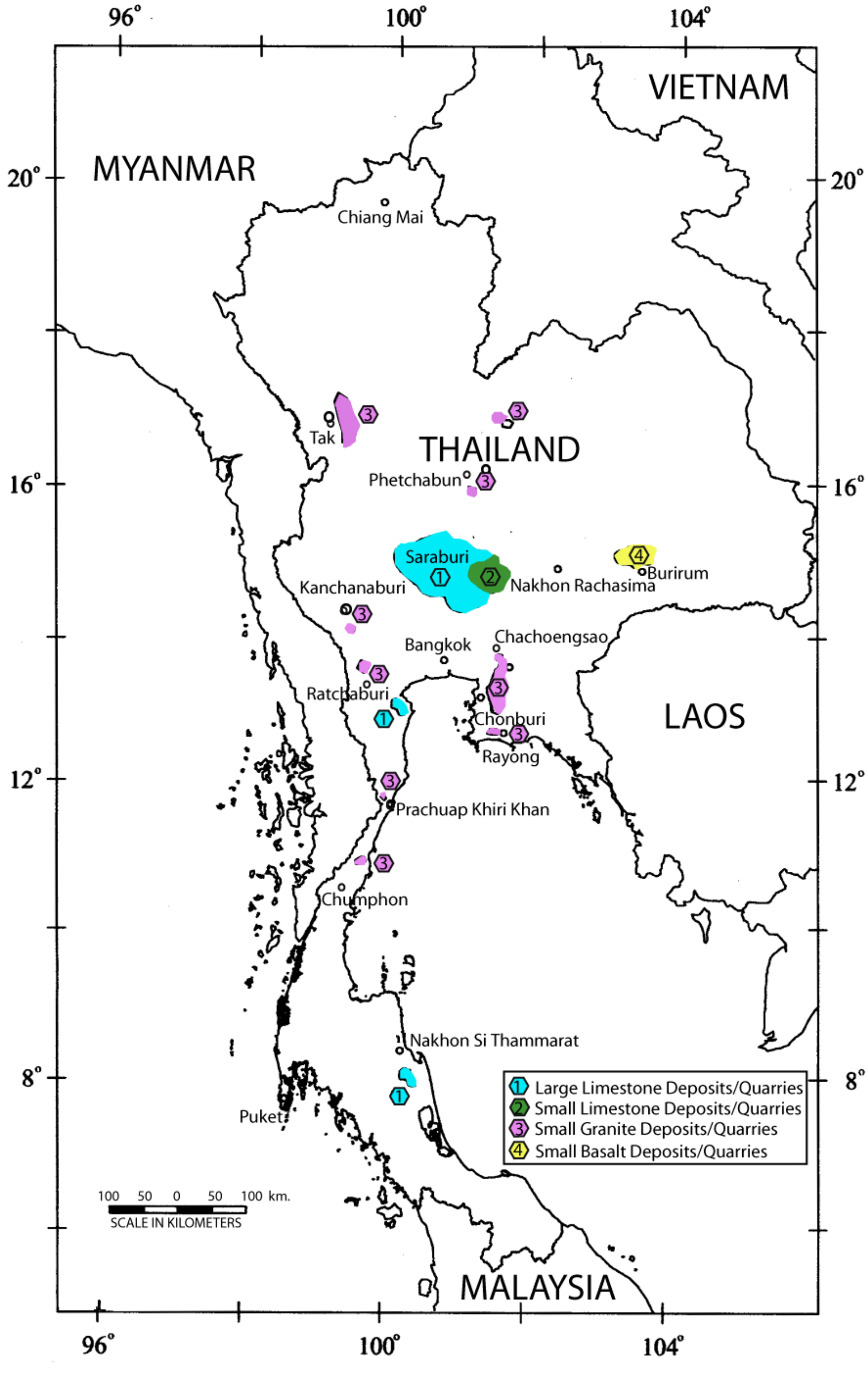

Figure 2. The survey map which shows the locations of rock deposits and operated quarries.

It is significant that the rock reserves and their production capacity within a 20 year period are adequate for this period. Only in a few provincial areas in Thailand will there be lack of rock materials in the short term. This problem can be solved by substituting the use of granite (or basalt) aggregate instead of limestone aggregate in those areas.

Figure 2 illustrates the location map of rock deposits and active quarries in Thailand. Areas of limestone deposit are indicated as 1 for large quarries, and 2 for small quarries. The locations of limestone are mainly in the central and southern part. Areas of other rock deposits are indicated as 3 for granite and 4 for basalt. Granite locations are in the western, northern and southern part. Basalt deposits are in the eastern and northeastern part.

EVALUATION AND RESOURCE RATING

The main purpose of the study was evaluation of selected rock resources at a number of sites using numerical procedures. There are three rating groups in the evaluation process. The factors concerned in the rating of each group are given below.

Rock resource characteristics

This assigned value of the first group is to evaluate the deposit characteristics of rocks. Rating factors are dependent on the topography, general geology, land use, and other agricultural and biogeographical factors of the area.

Resource economics

The second group signifies the rock reserve, the quality of rock mass, the appropriate potential sites for quarry and crushing plant, the current market status, and the construction trend.

Optimal excavation

The third group represents the optimal production plan which is dependent on the suitability of a specific site for excavation, the estimated overall costs of development, optimal design for the development, reclamation and utilization, and other specific factors.

To assign a quantitative value for each group, the highest numerical number for a rating is 4, and the lowest is 1. Only the category of 0.5 is allowed. The final numerical number for the whole rock resource is obtained by summation of three rating categories during the evaluation process. This final number is very useful in the selection process. Further assessment criteria are necessary for the suitability of the quarry and crushing plant sites. These sites may be reserved for additional sources of rock supply to satisfy the long-term rock consumption for a particular area.

An example of a field rating for a selected site of granite deposit (Silasomboonsap quarry) is shown in Table 1. There are 3 groups of numerical rating for this granite resource, and the final rating number is 8.5 from a maximum of 12. This is considered sufficiently economic to operate the quarry and crushing plant.

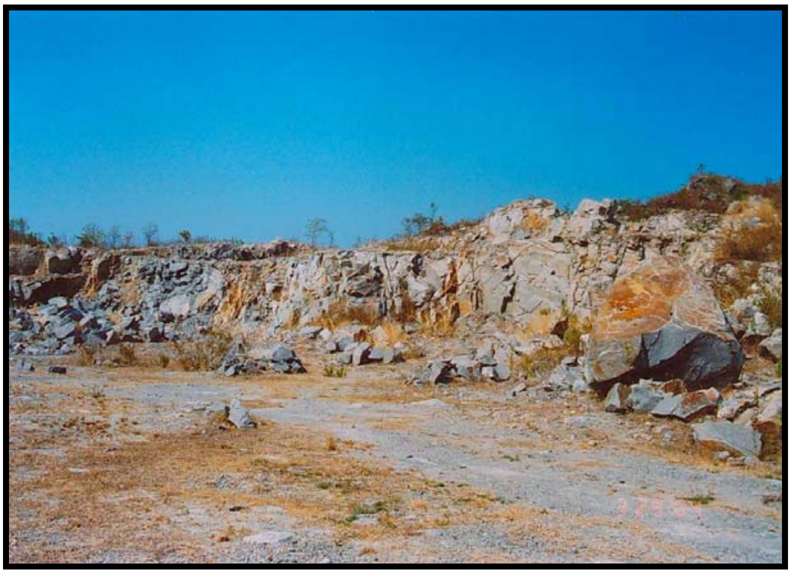

Figure 3. A cited quarry of potential granite resource in the western part of Thailand.

The cited granite quarry (Figure 3) for road aggregate and other civil construction materials is about 80 km west of Bangkok. This granite quarry is located close to a limestone quarry within a radius of 5 km. Both quarries are operated by the same company. The crushing plant is adapted to suit both granite and limestone by using different schedules of blasted rock feed. Since the excavation method for both quarries is not much different and the operator can use the same equipment, the company survived the depression period in 1997-2000.

Advantages points of the numerical rating methodology are that the evaluation method is quick, easy to use, and the rated values can be used as a database for digital mapping. For further improvement, an area of higher rating values (within the same range) can be shown on the map with one specific color to make its background different from other areas of lower rating values. The author expects that in the near future authorized personnel can use this technique as one of the compulsory procedures in granting permits for quarry development

Table 1. Designation values of the three rating groups for a small size granite deposit (Figure 3).

Quarry Name	Group Number	Group Title	Rating Factors Involved	Overall Rating Number	Summation
Silasomboonsap, Kanchaburi	1	Rock characteristics	Topography, General geology, Land use, Agriculture, Biogeography	2.5	8.5
	2	Resource economics	Rock reserve, Quality of rock mass, Suitability of sites, Market price	3.0	
	3	The optimal excavation	Suitability of cutting face, Overall unit costs, Design of development, Reclamation and utilization, Specific factors in the area	3.0	

BLAST ASSESSMENT AND OPTIMIZATION

Another research direction was to advise the suggested procedures for blast impact regulations. Steps of impact assessment and blast optimization were performed on trial quarries. The typical explosive charge was AN-FO plus gelatin dynamite, detonated with electric delay caps. At specific sites, the number of trucks loading the rock fragments were counted over a certain period of time in order to recheck the weight/volume of blasted rock at the quarry face.

Figure 4. Digital recordings for ground vibration and air blast during bench blasting.

A packed program, using the Delphi compiler, was proposed by colleagues. The algorithm aims to develop the bench blasting model that it is appropriate for both the appropriate dimensions and the charge weights (Tangchawal, 2004). The important input variables are explosive diameter, bench height, required rock volume, required drill holes, powder factor value. The important output results are burden, spacing, sub-drilling, stemming, total rock volume, explosive weight used.

An example of vibration prediction for control blasting was obtained from seven large quarries. The back analysis follows the modified trend line procedure as suggested by Birch and Pegden (2000). Regression equations of trend lines are indicated. The recommended value of permitted peak particle velocity on the level wher no damage occurred is 0.025 m/s (Wiss and Nicholls, 1974). According to the conventional square-root scaled distance theory, the design charge weights per delay for each safe distance are determined in Table 2.

The requirements for a typical blast operation are to provide the desired fragment sizes, but they should also be safe and economic. There may be more than one drill pattern to choose from the specific plan of output results. Cost analysis on various drill patterns could help to confirm the preferred option. Figures 5 and 6 are two graphs demonstrating the cost optimization of drill patterns for limestone quarries. An overall unit cost includes the costs of drilling, blasting, and loading at the quarry face.

Table 2. The design charge weights per delay (kg) for each safe distance of the seven large quarries.

Distance, m	Quarry 1, kg	Quarry 2, kg	Quarry 3, kg	Quarry 4, kg	Quarry 5, kg	Quarry 6, kg	Quarry 7, kg
150	117.41	75.71	66.98	130.64	64.31	133.73	160.85
175	159.81	103.05	91.16	177.82	87.53	182.02	218.93
200	208.73	134.59	119.27	232.55	114.32	237.74	285.95
225	264.18	170.34	150.70	293.95	144.69	300.89	361.91
250	326.14	210.30	186.05	362.90	178.63	371.47	446.80
275	394.63	254.47	225.12	439.10	216.14	449.47	540.63
300	469.65	302.83	267.91	525.57	257.23	534.91	643.40

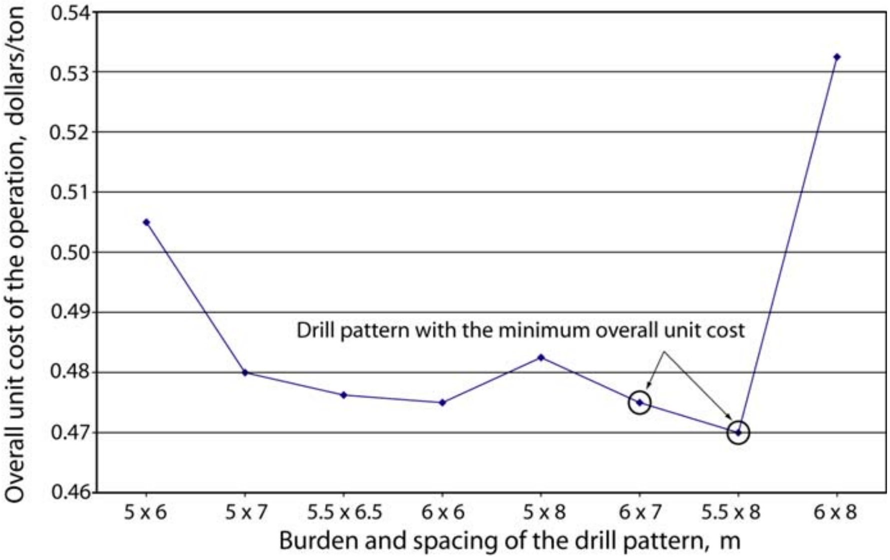

Figure 5. Results of selected drill patterns with the minimum cost for a large limestone quarry.

From our impact criteria, there are three stages of recommended regulations. These stages of impact control are the normal case, the awareness case, and the historic structure case. In any case, the statistical comparison must be within a 95 % probability limit. The normal case is to design explosive weights per delay in a quarry blast according to the modified trend line. The normal case is applied for the vibration prediction of field data, and its permitted peak particle velocity is 0.025 m/s.

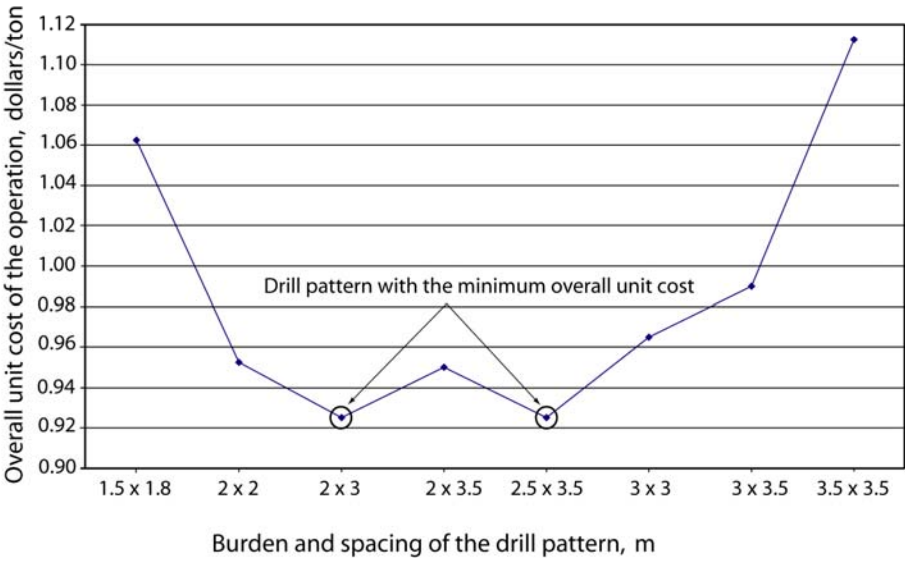

Figure 6. Results of selected drill patterns with the minimum cost for a small limestone quarry.

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

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

CONCLUSIONS

Principal objectives in quarry planning and evaluation are based on the appropriate rock reserves and a safe and economic excavation. From field studies, there are 3 types of competent rocks suitable for use in the construction industry. They are limestone, granite, and basalt. Although sandstone is widely distributed in the northeastern part of Thailand it usually cracks along the rock bed and is of insufficient strength to be used in construction. In the central part where there are many working quarries, limestone is a common rock material. In some areas especially near the national borders where there is a lack of limestone, other rock types such as granite and basalt are used. The proposed numerical rating method is a way to evaluate deposits before they are accepted as a rock reserve site for use in construction.

An important planning step in quarry operations is to determine the geometry of worked benches. If there are enough input data, one can execute via a design packed program an effective quarry design. When altering the geometry of the blast plan for each output pattern, a low cost of overall unit operation should be maintained.

Back analysis on results of fragmentation and damage from blast impacts can improve the schematic plan. In the normal area where the operated quarry is not near the community, the design explosive weights per delay may be such that the blasting will produce a specific safe distance with the peak particle velocity at 0.025m/s. There is no single plan that is appropriate for all quarry operations. The choice of methods depends upon the approach that is most acceptable for the specific site.

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