EVALUATING AND ASSESSING FACTORS INFLUENCING PRODUCTION IN A GRANITE FACTORY IN KINGDOM OF SAUDI ARABIA

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With the increasing demand for ornamental stones in Saudi Arabia and the opening of markets to imported products, a sharp competition has begun between domestic and imported granite products.Therefore, it was necessary for the local factories to provide encouraging and reasonable prices for the consumer while maintaining the quality and excellence. Thus, the factor of production is the one that controls the success of the factory or not. It is known that the process of improving productivity includes increasing production without adding any other costs, or reducing unit costs or both together.

This research aims to evaluate and assess the factors affecting the production line at the granite factory. It is the first production line where granite slabs are cut and processed in lenghts ranging from two meters to three meters, and vary in width between one meter and two meters; their thickness is constant and equals 2 cm. A mathematical equation has been developed to show the relationship between productivity, in a square meter, for the shift and the factors influencing this productivity, with the aim of evaluating and assessing these factors.

INTRODUCTION

Granite rock is the hardest and most beautiful stone used in building.Therefore; it is widely used in construction work in Saudi Arabia. Kingdom of Saudi Arabia used to import granite ready for construction work from Italy, Brazil and Spain until recently, despite the existence of huge quantities of these raw materials in our territory. Despite the low price of the imported granite compared with the local one. Mining granite rock has begun in the Kingdom, and local factories have emerged and began to compete with the imported granite. The average price of imported granite is 90 saudian riyals per square metre, while the average price of local granite is 150 saudian riyals per square metre.

Therefore, it is essential for the local factories to find ways to reduce production costs and increase productivity while maintaining quality in order to obtain a position in the domestic market. This research has been conducted as an attempt to evaluate and assess the factors affecting the first production line in the granite factory in Saudi Arabia in order to reach higher productivity of this line.

It is well known that the production of granite passes several stages before its slabs are ready for use in construction work. These stages can be summarized as follows:

1. Extraction of granite blocks from the quarry and transporting them to the factory.
2. The process of cutting blocks to plates and slabs by multi-saws cutting machines.
3. The process of cutting the sides, polishing and roughing them into pieces with different dimensions based on the market demands.

In the first production line, they use multi-saws cutting machines, which is operated by electric power and it is about 35 saws. These saws cut ornamental blocks to a fixed plate/slab thickness of 2 cm with dimensions of slabs/plates ranging between one meter and three meters, according to the size of rock blocks brought from the quarry. Cutting a rock block usually takes between one hundred to two hundred hours of work. Therefore, the attempt to reduce this time will reduce the production costs.Reducing the time required to cut rocky blocks means increasig the number of square meters produced in the same shift.The shift equals eight hours. The productivity of the first production line can be calculated by the following equation:

$$Ps = [(P) / (T)] \times 8.0 \tag{1}$$

Where:
Ps = the productivity of the shift in square meters,
P = the number of square meters resulting from a rocky block, and
T = time required to cut a single block of rock into slabs in hours.

Many researchers have studied the sawability of rocks. Slab production and rock properties evaluated using multiple curvilinear regression analysis and estimation models were developed [1]. Rock tensile strength and impact strength were included in the best model [2-4] . Alternative models, including Schmidt hammer value, point load strength, impact strength and *P*-wave velocity, are recommended for the rapid estimation of the sawability of carbonate rocks [1, 5].

FACTORS AFFECTING THE PRODUCTIVITY OF THE FIRST LINE

In order to increase the productivity of a single shift or reduce the time required to cut a single square metre, it is a must to study and evaluate the factors affecting the production of this line. It was initially supposed tha several factors may affect the production.They are as follows:

1- Hardness of the rock, it depends on the quality of rock to be cut.
2- The dimensions of the produced slabs which include length, width and thickness.
3- The number of slabs to be cut from the rock mass.

The study covered seven different types of ornamental stones that differ in hardness according to the rock constituents as shown in Table 1.

Table 1: Type of ornamental stones used in the study and the percentage of their mineral constituents

Commercial name of rock	Mineral constituents%	
	Quartz	Feldspar
Violetta	20	79
Biack orchids	-	100
Crown red	15	85
Silver Pearl	15	85
Manzonite	-	99
Golden leave	30	69
Tropic brown	15	85

It is known that the hardness of the rock depends on the different ratios of the constituents of this rock. These constituents represented by the percentages of quartz and feldspar provided in Table 1The second factor, which is the dimensions of the slabs, includes length, width and thickness. Since the thickness of produced slabs is fixed (2 cm), it can be excluded from anaysis. That's why we can rewrite the above second factor (dimensions of produced slabs) to be read as follows:

1- The length of slabs produced, in meters.
2- The width of slabs produced, in meters.
   Therefore, the factors influencing the production of the first line are as follows:
1- The proportion of Quartz in the rock block (%).
2- The proportion of Feldspar in the rock block (%).
3- The length of slabs produced, in meters.
4- The width of slabs produced, in meters.
5- The number of slabs produced from a single rocky block.
6- The time required to cut a rocky block in hours.

The data was collected after cutting 99 rocky blocks. This data includes the six factors mentioned above and the productivity of the first production line measured in square meters resulted from a single rocky block. A mathematical equation has been established linking the six factors and productivity in square meters.

THE RELATIONSHIP BETWEEN PRODUCTIVITY AND THE FACTORS AFFECTING THE PRODUCTION OF THE FIRST LINE

The data has been collected in files. After cutting blocks, the time required to cut a single rocky block ranged between one hundred and two hundred hours. The data has been put into files using TSP soft ware [6] . The data include the following:

1- Productivity in square meters per each rocky block.
2- The time required to cut a rocky block,in hours.
3- The proportion of Quartz in the rocky block (%).
4- The proportion of Feldspar in the rocky block (%).

5- The length of slabs produced, in meters.
6- The width of slabs produced, in meters.
7- The number of slabs produced from a single rocky block.

The dimensions of the produced slabs are equal for a single rocky block. Table 2 represents a sample of this data. It also shows the symbols of the factors affecting the productivity (variables).

Table 2: Sample of data from one file

Productivity $(m^2$/block) P	No. of slabs N	With (m) W	Length (m) L	Time of cutting (hr)	Quartz (%) Q	Feldsp (%) F
338.4	75	1.75	2.54	145.50	25	75
428.8	81	1.88	2.77	131.50	5	95
361.4	92	1.65	2.35	197.00	20	80
277.54	84	1.65	2.05	196.50	–	100
267.05	86	1.30	2.35	111.00	15	85
282.90	89	1.45	2.15	144.25	30	70
379.98	86	1.80	2.45	163.50	50	50
390.69	91	1.65	2.50	197.00	15	85
252.74	86	1.40	2.20	140.50	30	70

Through the TSP program, we can calculate the productivity in square meter in a single shift (Ps) for each rocky block by using the equation No. (1) without resorting to increasing the number of data. Since the variable P could be calculated through the variables N, T, P, the Ps represents three variables mentioned, so we can exclude these three variables from the mathematical analysis.

After the data entry for all rocky blocks in files using TSP; a correlation was found between productivity in square meter in a single shift (Ps) on one hand as a dependent factor and the other four factors as independent factors on the other hand; they are : F, Q, W, L, as illustrated by the following equation:

$$Ps = - 10.97 - 0.12F - 0.11 Q - 1.34 W + 17.63L \qquad (2)$$

Where:

Ps   Productivity per shift   F   % of Feldspar
W   width of slabs, m   Q   % of Quartz
L   Length of slabs, m

The $R^2 = 80.9\%$ and the rate of error = 3.0 .This is an excellent result compared to the R^2 and the error rate [7], but it was noted that the factor of variables Q, F are low, which means that the impact of these factors on productivity is very limited, and based on this philosophy, these factors were excluded , and the equation was redone using the TSP. The following equation was obtained:

$$Ps = - 20.92 – 5.586 W + 19.84L \qquad (3)$$

The $R^2 = 79\%$ and the rate of error = 2.2.

It is noticeable that the constant numerical coefficient (20.92) factor in the equation No.(3) has decreased, which means that the impact of the rest of the same variables (W,L) in the equation has been reduced than in equation No.(2). Thus, we can conclude that rock constituents have effective influence in productivity, and they can not be excluded .However their impact is small.Therefore, quation No. (2) remains the most accurate one in describing the relationship between productivity and variables affecting productivity of the first line in the granite factory.

ANALYSIS OF THE RESULTS

It is clear from equation No. (2) that the productivity of the first production line will increase by 17.63 m^2 in a single shift for a single rocky block if the length of the slab increased by one meter . If the width of the slab increased by one meter, there is a shortage of production in a single shift for a single rocky block estimated by 1.34 m^2. If the proportion of quartz is increased by 10%, the productivity decreases by 1.1 m^2 in a single shift for a single rocky block. If Feldspar increased by 10%, the productivity decrease by 1.2 m^2 in a single shift. After application of the equation No.(2) above on some pices of data, , it became obvious that the outcomes of the equation of the real data are close to each other as shown in Table 3.

Table 3: Comparison of the actual productivity to the calculated by equation No.(2)

Productivity/ shift m^2 Ps		Feldspar (%) F	Quartz (%) Q	Slab width (m) W	Slab length (m) L
Using equation No.2	Actual				
19.82	18.6	75	25	1.75	2.54
16.30	14.7	95	5	1.65	2.35
16.92	19.2	80	20	1.3	2.35
18.89	16.1	100	0	1.65	2.5
14.10	14.4	85	15	1.4	2.2
18.11	18.6	70	30	1.8	2.45

This research did not take into account the impact of the capacity, speed and the time period for failure of the saws because all the saws are currently operating very efficiently and their capacity are more or less equal. Perhaps the human factor has an influence on the operation of the saws at full efficiency, and therefore this research recommends studying the impact of the human factor on the ability of production of the first line. Since it is known that the human factor has a clear impact in raising the efficiency of any production line. It is not strange to see that the same equipment run in two different factories and vary in their productivity due to the difference in the human factor in the two different factories [8]. Further study is required to check the validity of the derived equations for other rock types. In addition, the effect of the type of saw could be studied.

CONCLUSIONS

In this research, the factors affecting the first production line in a granite factory in the Kingdom of Saudi Arabia has been evaluated and assessed. It has been reached that the following factors are directly affecting the production of the first line: the proportion of quartz and feldspar in the rock; the length and the width of slabs produced in meters.

These factors have been linked mathematically to productivity in square meter for a single shift. It was found that the length and width of a slab are the most important factors affecting productivity in the first line of the factory. The second important factors are the mineral constituents of the rock. Although the impact of the rock constituents is limited, it must not be overlooked. It can be argued that the increase in the length of rocky blocks and increase in the number of saws would increase productivity, and thus, it could contribute to the reduction of production costs of the factory. This research did not take into account the impact of the capacity and speed of the saws and the time period for their failure because all the saws are currently operating very efficiently and their capacity is equal, to a great extent. Perhaps the human factor has an influence in the operation of the saws at full efficiency, and therefore this research recommends studying the impact of the human factor on the ability of production of the first line. Such study will assess and recognize the impact of the human factor of workers and supervisors on the productivity and thus attempting to raise production capacity of this premise.

REFERENCES

1- Unver, B.: "A statistical method for practical assessment of sawability of rocks", In: M. Barla, Editor, Eurock'96, Balkema, Rotterdam, pp. 59–65, (1996).

2- Wright, D.N. and Cassapi, V.B.: "Factors influencing stone sawability", Ind. Diamond Rev **2** ,pp. 84–87,(1985), <u>View Record in Scopus</u> | <u>Cited By in Scopus (10)</u>

3- Hausberger,P.: "Causes of the different behaviour of rocks when machined with diamond tools", Ind. Diamond Rev **3** ,pp. 1–25 , (1989).

4- Burgess, R.B.: "Circular sawing granite with diamond saw blades", In: Proceedings of the Fifth Industrial Diamond Seminar,. pp. 3–10, (1978).

5- Ceylanoglu,A. and Gorgulu,K. : " The performance measurement results of stone cutting machines and their relations with some material properties ", In: V. Strakos, V. Kebo, L. Farana and L. Smutny, Editors, Proceedings of the Sixth International Symposium on Mine Planning and Equipment Selection, Balkema, Rotterdam, pp. 393–398 ,(1997)

6- Lilen, D. M.: "TSP Softawre, Quantitative Micro Software" Irvin, California. (1990).

7- Hall, R. E., Jack Johnson, and David, M. Lilien:"Micro TSP User's Manual, Quantative Software" Irvin, California. , (1990).

8- Stefanko, R.:" the Coal Mining Technology Theory and Practice", SME, New York.,(1973).

تقويم العوامل المؤثرة في الإنتاج في مصنع للجرانيت

مـع ارتفاع الطلب على أحجار الزينـة في المملكة العربية السعودية و انفتاح السوق و دخول الجرانيت المستورد و منافسته للجرانيت المحلي بدأت المنافسة تحتد في السوق المحلية, لذلك كان من الضروري على المصـانع المحلية إنتاج الجرانيت بأسعار منافسة و جودة عالية حتى تحتفظ بحصتها في السوق المحلية . ومن المعروف أن العوامل المؤثرة في الإنتاج لها دور فاعل في المحافظة على الجودة و زيادة الإنتاج دون أي تكاليف إضافية . لذلك فإن هذا البحث يهدف إلى تقويم العوامل المؤثرة في خط الإنتاج الأول في أحد مصانع الجرانيت و هو عملية قص الكتل الصخرية إلى ألواح بواسطة آلة القطع متعددة المناشير و التي تعمل بالطاقة الكهربائية يبلغ عددها 35 منشارا حيث تقوم هذه المناشير بقص الكتل الصخرية إلى بلاطات بسمك ثابت = 2 سم وتتراوح أبعاد الألواح بين المتر إلى ثلاثة أمتار بناء على حجم الكتل الصخرية المجلوبة من المحجر . و قد تم بناء نموذج رياضي لإيجاد العلاقة بين الإنتاجية في الوردية الواحدة و العوامل المؤثرة في الإنتاج بهدف تحليل هذه العوامل و الاستفادة منها في رفع الإنتاجية.