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EFFECTS OF THE THICKNESS OF BLOCK CUTTING MACHINE GANG SAW ON WASTE PERCENTAGES AND PRODUCTIVITY

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ABSTRACT

This paper aims at studying the stone waste percentages generated from cutting stone blocks into slabs using stone block cutting machine (Gang Saw). This type of stone waste is in the form of powder (fine stone particles) mixed with cooling water and converted to mud or slurry.

Practical data for the Input (stone blocks) and the output (stone slabs) for this machine was collected from different stone companies in Palestine as random sample. Statistical analysis was carried out for these data related to the thickness of stone slabs. The practical results were investigated, calculated and compared with the ideal values, (ideal values were calculated theoretically for one cubic meter of stone block with dimensions of one meter length, one meter width, and one meter height).

This study shows that, there is inverse relation between the cutting thickness of the gang saw (which equals the thickness of produced stone slabs) and the volume waste percentages and productivity (area of stone slabs produced in square meters per one cubic meter of stone block). Also, the volume waste percentages fluctuate around the ideal values which are 26% for 2cm, 19% for 3cm and 22% for the mixed 2&3cm thicknesses.

1 INTRODUCTION

Stone and Marble industry in Palestine is considered one of the conventional and historic industries. Researches were in agreement with the fact that Palestine is one of those countries in which raw material for construction stone is available at commercial quantities, and distinguished for its type, quality and multicolor. About 742 facilities (official and unofficial) work in stone and marble industry with more than 13,500 workers engaged in the stone sector [1]. The Palestinian Production of stone is about 4% of the world's stone production [1]. This sector contributes approximately 25% to the overall Palestinian industrial revenue, and 4.5% of the total Palestinian gross domestic product [1].

Processing of natural stone aims to produce finished (e.g. tiles) or semi-finished (e.g. slabs) products in order to cover the market needs. During the production processes considerable amounts of waste are generated [2].

Stone slurry is a semi-liquid substance consisting of particles originated from the sawing and polishing processes and water used to cool and lubricate the sawing and polishing machines [3]. Slurry is created from all stone cutting operations when the cooling water mixes with the fine stone particles. It is collected and recycled in appropriate installments in order to recycle the water into the production process. Using press filters the water recovery can reach up to 90% still leaving a material called sludge with a high humidity content (22-28%) [2].

There are two types of block cutting machines; Stone machine of two-way cutting machine (which is known as Mangal in stone industry and can cut out the stone blocks into stone strips with certain thickness and maximum width of about 60cm). The second type is a Gang Saw machine which cut out the stone blocks into large slabs with certain and specific thicknesses. 2cm and 3cm are the most used thicknesses in stone factories and known as standard thicknesses in the stone industry in Palestine. Factories that have only one gang saw sometimes fix the cutting thickness into 2cm and 3cm and produce part of the stone block into slabs with thickness of 2cm and the rest of the stone block into slabs with thickness of 3cm.

The idea of this paper is to study percentages of stone waste during cutting stone blocks by Gang Saw into slabs, because most of the waste of this machine is converted to powder and mixed with water, to become as slurry or sludge. Also, this type of waste is intangible or invisible as the other waste types like the cracked stone.

2 LITERATURE REVIEW

The greatest waste concern in the stone industry is stone itself, specifically in the forms of overburden, screening residual, wastewater sludge, fines, and stone fragments. In 2006, a survey of the natural stone industry conducted by the University of Tennessee Center for Clean Products (UT) indicated that anywhere from 3-93% of the total material quarried is wasted [4], while other studies report values from 15% to 78% [4]. Additional waste is generated from fractured blocks, the sawing and polishing processes, and the rejection of broken or damaged slabs. One study approximates that for every 1000 tons of marble quarried, only about 70 tons will be used in a completed building [4]. Construction also creates large amount of waste due to the stringent requirements for visual appeal; it is estimated that 75% of the stone used to build decorative pieces is discarded as waste through the cutting and shaping process [4].

Quarrying activities which include the extraction of stone resources can deliver from 50 to 95% waste material [5] while in the subsequent phases of processing up to 41 % of the original input material is turned into waste [6]. Data for 2003 concerning the world stone production indicate that the net quarry production was 75,000,000 tons per year while the respective amount of generated waste was 78,750,000 tons per year, which corresponds to 51% of gross quarry production [7].

The processing waste can be classified in three main categories depending on the size of the piece; Large to medium size waste called scrap and comes from broken or defective slabs whose surface might be polished, medium to small size waste consisting of splints, flakes, chips which are created during trimming of blocks or slabs, and, small size waste consisting of fine particles and has the form of dust or slurry [2].

Stone industry is an important factor in worldwide economy. Despite this, a large amount of residues is produced in ornamental stone industry with different dimension and particle size [8]. There are two types of natural stone processing waste: solid and semi-liquid or slurry [9].

In fact during the marble cutting process by gang saw, water is used as a coolant and the powder flows along with it as waste marble slurry [8]. Depending on the kind of process involved, the sludge generated is equal to between 20-30% of the weight of the stone worked [10].

3 METHODOLGY OF CALCULATIONS

This survey was carried out by taking real and realistic readings for the quantities of stone blocks in cubic meters (m^3) entering to the gang saw (block cutting machine) and the quantities of stone slabs produced from this machine in square meters (m^2). About 120 reading samples were taken from different stone companies and from different areas in Palestine. This study was carried out for gang saw cutting stone blocks into slabs with 2cm, 3cm and mixed 2 & 3 cm thickness slabs.

Every practical reading represents a full load of stone blocks for the gang saw and takes about 12 working hours till finishing sawing the stone block and records this reading. The dimensions of the stone block (length, width, and height) were taken and recorded before entering the gang saw (figure 1) then the quantity (volume) of stone blocks was calculated in cubic meters.

After finishing sawing or cutting the stone block (figure 3), the dimensions of produced slabs (length, height, thickness, and number of slabs) were taken and recorded, then the quantity (volume) of produced stone slabs were calculated in cubic meters.

Figure 1 represents two stone blocks prepared for cutting into slabs, in one of the Palestinian stone factories; using gang saw machine and it represent a full load for the gang saw. The length, width and height of these blocks were recorded, and then the quantity of stone blocks (volume) was calculated in cubic meters.

Figure 1: Stone blocks prepared for cutting into slabs using gang saw machine

Figure 2 represents the stone blocks during cutting process using the gang saw into slabs with 2cm thickness. During this process the stone is wasted in the form of powder as a result of the sawing process and mixed with the cooling water and left into in the form of slurry. In the stone factories about 12 working hours needed for sawing such stone blocks into slabs and the time of sawing depending mainly on the height of the stone block in addition to the hardness of stone, working hours of the gang saw blades, …etc., which means two full loads of stone blocks can be produced or sawed every day.

Figure 2: Gang saw machine during cutting stone blocks

Figure 3 represents stone slabs with 2cm thickness produced from sawing the stone blocks in figures 1 and 2. The length, height and thickness in addition to the number of stone slabs were recorded then the quantity of produced slabs was calculated in cubic meters by multiplying the length times the height times the number times the thickness of stone slabs.

Figure 3: Produced stone slabs with 2cm thickness

The practical findings and results were compared with the ideal calculated values. The ideal calculations were based on an assumption of cutting one cubic meter (1 m^3) of stone block by a gang saw into stone slabs with 2cm, 3cm then mixed 2&3cm thicknesses with a gang saw Blade Diamond Thickness of 6.5mm.

3.1 Equations needed for calculations:

The below mathematical equations were used during this study to calculate the volume of stone blocks entering into the gang saw (Qin), the ideal number of stone slabs produced from 1 m^3 of stone block (N) by dividing the width of stone block on the (thickness of the stone slabs + the thickness of the gang saw diamond blades), the area of produced stone slabs (A), the productivity of one cubic meter of stone blocks entering the gang saw which means how many square meters of stone slabs can be produced from 1m^3 of stone blocks (P), the volume (quantity in cubic meters) of produced stone slabs (Qout) which calculated by multiplying the area of the produced stone slabs with the thickness of the produced slabs, the quantity of stone wasted after cutting stone blocks into slabs (W), and the percentage of stone waste (%W).

$$Qin = L * Y * H \tag{1}$$

$$N = \frac{Y}{(TS + TD)} \tag{2}$$

$$A = L * H * N \tag{3}$$

$$P = \frac{A}{Qin} \tag{4}$$

$$Qout = A * TS \tag{5}$$

$$W = Qin - Qout \tag{6}$$

$$\%W = \frac{W}{Qin} * 100 \tag{7}$$

Where:

Qin: The quantity (volume) of the stone blocks entering to a gang saw for cutting into slabs, m^3

L: The length of the stone blocks and also equal the length of produced stone slabs, m

Y: Width of the stone blocks, m

H: The height of the stone blocks and also equal the height of produced stone slabs, m

N: Ideal (calculated) number of stone slabs produced from one cube of stone blocks.

TS: Thickness of the produced stone slabs, cm

TD: Thickness of the gang saw blade diamond (which is 6.5mm as an average in the stone factories)

A: Area of the produced stone slabs, m^2

P: Productivity which represents the quantity of stone slabs produced from one cube of stone blocks, sqm/cube

Qout: The quantity of produced stone slabs, m^3

W: Quantity of stone wasted after cutting stone blocks into slabs (which represents the difference between the quantity of stone blocks entering the gang saw and the quantity of stone slabs produced from the gang saw), m^3

% W: The percentage of stone waste for gang saw machines.

Note: Cube: means 1 m^3 of stone block with L=1m, Y=1m and H=1m

and sqm: means m^2

4 RESULTS AND DISCUSSION:

The results in table 1 represent ideal values and they were calculated based on an assumption of cutting one cube of stone block (L=1m, Y=1m, H=1m) into stone slabs with 2cm, 3cm, and mixed 2&3cm thicknesses.

These calculations were carried out using the previous mathematical equations and it was noticed that for every $1m^3$ of stone blocks entering the gang saw there is about 0.26 m^3, 0.19 m^3 and 0.22 m^3 of stone wasted as powder for 2cm, 3cm and mixed 2&3 cm of stone slabs respectively.

The ideal number of produced stone slabs were calculated using equation number (2) for each cutting thickness (TS=2cm, 3cm, and 2.5cm) and using the gang saw blade diamond thickness of 6.5mm (TD=0.65cm).

Also, it was noticed that for every $1m^3$ of stone blocks entering the gang saw $37m^2$, $27m^2$, and $31m^2$ of stone slabs produced with thicknesses of 2cm, 3cm and mixed 2&3cm respectively.

Table 1: Ideal calculated values of stone waste percentages and productivity of a one cube of stone block after cutting into slabs by a gang saw

Parameter	**Thickness of gang saw cutting** (Thickness of produced stone slabs)		
	2cm	3cm	Mixed 2&3cm
Qin, m^3 (assumed 1 m^3)	1	1	1
N, number of produced slabs from 1m	37	27	31
A, area of the produced slabs from 1 m^3 of stone block, m^2	37	27	31
P, productivity (m^2 of slabs produced from $1m^3$ of stone block), m^2/cube	37	27	31
Q out, m^3	0.74	0.81	0.78
W, cube or m^3	0.26	0.19	0.22
% W (ideal percentages)	26	19	22

Note: In table 1, for mixed 2&3cm gang saw, an average thickness of 2.5cm slabs was assumed and used.

The practical results in table 2 show that about 49 m^3 of stone wasted as powder when 181 m^3 of stone blocks were cut into stone slabs with 2cm thickness and 77.67 m^3 of stone wasted as powder when 364.76 m^3 of stone blocks were cut into stone slabs with 3cm thickness. The quantity of stone wasted as powder ranges from about 21% till 27% for 2cm and 3cm thicknesses respectively. It is found that there is an inverse relation between the cutting thickness and the waste percentages and also there is inverse relation between the cutting thickness and the productivity.

There are many studies supporting the results that were obtained in table 2. One of these studies indicates that as the thickness of product increases, the portion of waste is reduced [11]. It is also estimated that 20% to 25% of the marble/granite produced results in powder in the form of slurry, as for each marble or granite slab of 20mm produced; 5mm is crushed into powder during the cutting process and this powder flows along with water forming marble slurry [11].

Table 2: Quantities of input and output of stone from the gang saw, ideal and practical results of waste and productivity per one cube of stone block

Gang saw Thickness	**Qin m^3**	**A m^2**	**P, m^2/cube**		**Q out M^3**	**W M^3**	**% W**	
			Ideal	**Practical**			**Ideal**	**Practical**
2cm	181.11	6600.10	37.00	36.44	132.00	49.11	26.00	27.11
2 & 3 cm	202.99	5851.98	31.00	28.83	153.40	49.59	22.50	24.43
3cm	364.76	9569.63	27.00	26.24	287.09	77.67	19.00	21.30
Total	748.86	22021.76	---	---	572.49	176.37	---	---

Figure 4 shows that the percentage of waste for a gang saw cutting blocks into slabs with 2cm thickness ranges from about 23 to 32% and most of the reading percentages fluctuate around the ideal calculated value which is 26%.

Figure 4: Percentages of stone waste for gang saw cutting into 2cm slabs

From figure 5, the percentage of waste for a gang saw cutting blocks into slabs with 3cm thickness, ranges from about 15 to 29% and the reading percentages fluctuates around the ideal value which is 19%.

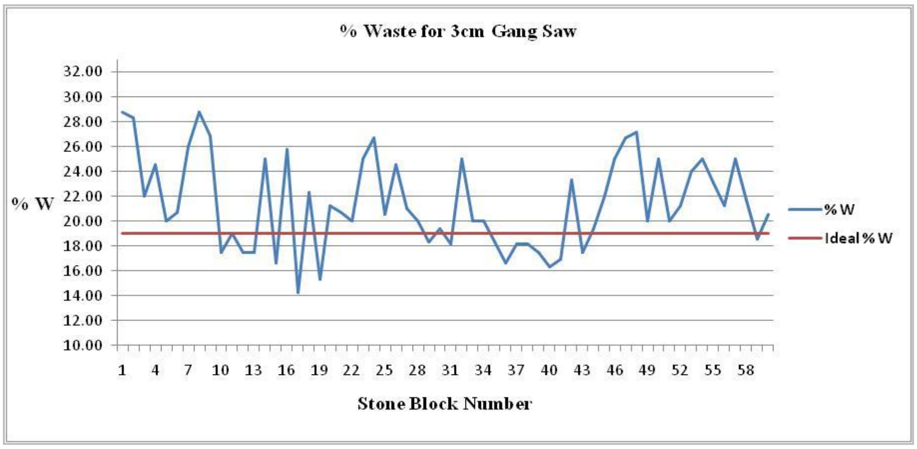

Figure 5: Percentages of stone waste for gang saw cutting into 3cm slabs

Figure 6, illustrate that the percentage of waste for a gang saw cutting blocks into slabs with mixed 2&3cm thickness, ranges from about 18 to 29% and the reading percentages fluctuates around the ideal value which is 22.5%.

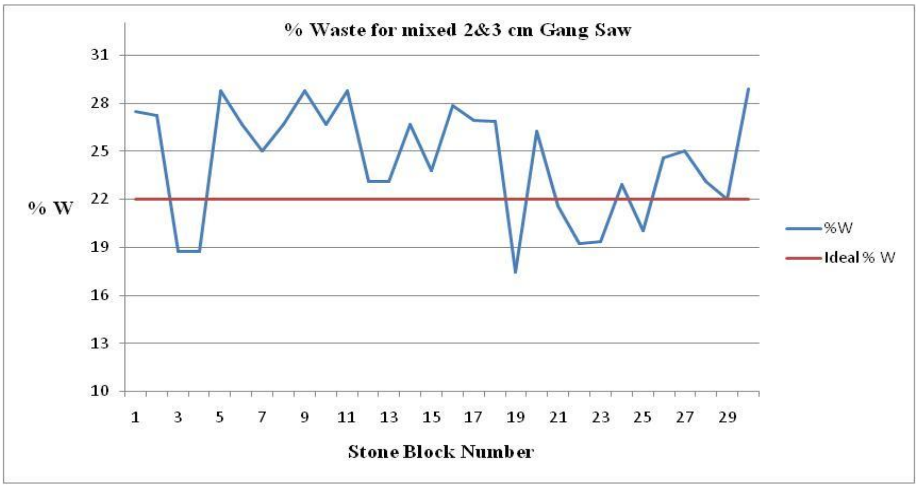

Figure 6: Percentages of stone waste for gang saw cutting into mixed 2 & 3cm slabs

It is also found from figures (4, 5, 6) that most of the practical values of the waste percentages are more than the calculated ideal values, and this is applicable with industrial reality in general. (Always the practical waste percentages are greater than the ideal values and it is preferable to minimize the waste percentage to be as close as possible to the ideal values).

Figure 7, indicates that large quantity of stone was lost as powder in the form of slurry during cutting or sawing stone blocks by gang saw machines. In this survey about 176 cubes of stone was lost and converted to slurry, from about 749 cubes of stone blocks entered to gang saw machines and sawed into slabs with 2cm, 3cm and mixed 2&3cm thicknesses.

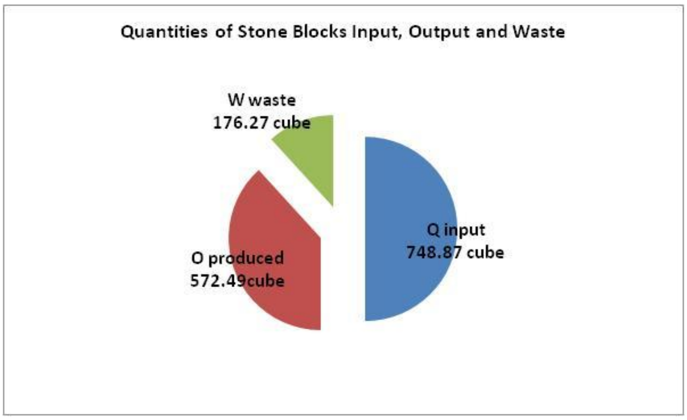

Figure 7: Total quantities of stone enter as blocks, produced as slabs and wasted in the form of slurry for gang saw machines cutting in 2cm, 3cm and mixed 2&3cm

Waste (W) represents the amount of stone waste that has been turned to powder, regardless of the amount of damaged panels or panels that contain fractures or deformities in color or quality.

Figure 8 shows that, there is an inverse relationship between the thicknesses of stone slabs produced by gang saw machines and the percentage of stone waste. This figure also illustrates that the average waste percentage is greater than the ideal values for the three cutting thicknesses.

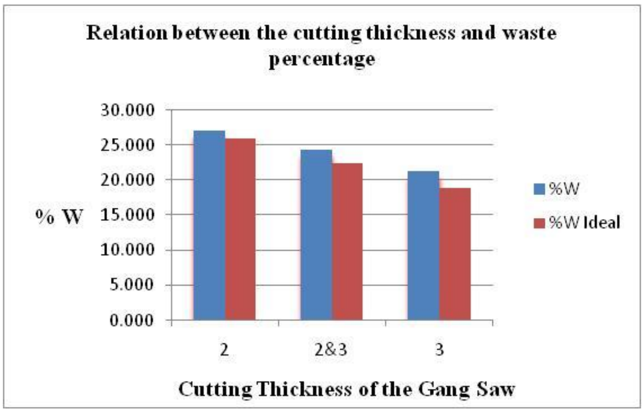

Figure 8: Relation between the cutting thickness of the gang saw and the average waste percentage

Figure 9 indicates that, there is an inverse relationship between the thickness of stone slabs and the productivity, (i.e. when the cutting thickness for stone blocks increased, the area of stone slabs produced decreased). Also, this figure shows that the average productivity is less than the ideal values for the three cutting thicknesses.

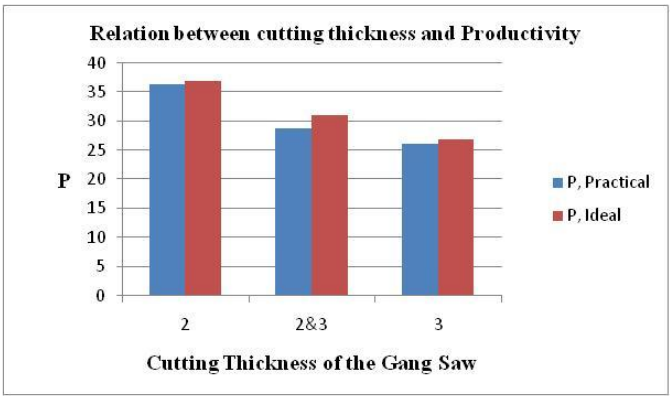

Figure 9: Relation between the cutting thickness of the gang saw and the average productivity of stone (m^2 /cube)

5 CONCLUSIONS

This study shows that, huge quantities of stone were lost during cutting or sawing stone blocks into slabs by gang saw machines and all stone is wasted is in the form of powder and mixed with the cooling water and converted to slurry, and this type of waste is intangible or invisible like the other waste types such as the cracked or the rejected stone.

The cutting thickness (i.e. the thickness of produced slabs) plays the major factor for the percentage of waste, and there is an inverse relation between the cutting thickness and the percentage of waste. The practical average waste percentages are 27.11%, 24.43% and 21.3% for 2cm, mixed 2&3cm and 3cm cutting thicknesses respectively.

The gang saw blade diamond thickness also affects the percentage of waste despite there are standard and fixed thicknesses for it, which is used 6.5mm in this study.

The productivity of stone blocks (i.e. the area of stone slabs produced from one cube of stone block) are inversely proportional with the cutting thickness. The average of practical productivities are 36.44 sqm/cube, 28.83 sqm/cube, and 26.24 sqm/cube for 2cm, mixed 2&3cm and 3cm cutting thicknesses respectively.

6 RECOMMENDATIONS

- To decrease the percentage of waste for cutting stone blocks by gang saw machines and other stages of stone processing, it is recommended to remove the impurities and protrusions from edges of the stone blocks before cutting by the gang saw machines, and this will increase the production capacity for the gang saw.

- Since there are huge quantities of slurry resulted from cutting stone blocks using gang saw machines, the color and quality of stone blocks must be suitable for the order and fit the color shades of the customer sample.

- Selection of the best available equipment and technique for the decantation and treating the slurry or mud like filter presses, in order to get maximum and pure recycle of cooling water.

- Since there are huge quantities of mud or slurry, it is recommended to treat the slurry and reuse it in certain products and industries.

- Transport and collect the slurry and sludge by specialized people or companies and store them in certain and suitable places to decrease their effect on the environment.

- Since there is inverse relation between the cutting thickness of the gang saw and the quantity of stone slabs produced, it is recommended to find relation between the cutting thickness and the selling price of the stone slabs.

- Buying gang saw blades with minimum diamond thicknesses available in the market.

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