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Analysis Cutting Performance of Insulation Blocks by Diamond Disc Block Cutter Machines

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Abstract

In this study, cutting performance of insulation blocks by diamond disc block cutter machines were analyzed. A single line lightweight masonry block with 200 mm × 400 mm × 200 mm dimension (width × length × height) was produced to produce an insulation block by using circular saw block cuttingmachine for the first time. In variation experiments involving the cutting of insulation blocks, the power consumption, cutting forces, and specific energy values were obtained. The optimum cutting parameters were determined by analyzing the obtained data. Performance experiments were conducted with optimum cutting parameters. In the variation and performance experiments, cutting forces, power consumption, and specific energy values were obtained. The optimum cutting performances block samples and the composition of the diamond socket used in the industry were determined.

Keywords: Insulation Block, Cutting Performance, Diamond socket circular saw, Cutting forces, Power consumption, Specific energy

Dairesel Testereli Blok Kesme Makinelerinde İzolasyon Blokların Kesme Performansı Analizi

Özet

Bu çalışmada, dairesel testereli blok kesme makinaları ile izolasyon blokların kesim performansları belirlenmiştir. İzolasyon bloğu üretimi için ilk defa dairesel testereli blok kesme makinesi kullanılarak 200 mm x 400 mm x 200 mm (en x boy x yükseklik) boyutlarında tek sıra boşluklu duvar hafif blok elemanı üretilmiştir. İzolasyon bloklarının kesilmesinde varyasyon deneylerinde, güç tüketimi, kesme kuvvetleri ve spesifik enerji değerleri elde edilmiştir. Elde edilen verilere analitik bir yaklaşım uygulanarak optimum kesme parametreleri belirlenmiştir. Bulunan optimum kesme parametreleri ile performans deneyleri yapılmıştır. Varyasyon ve performans deneylerinde, kesme kuvvetleri, güç tüketimi ve spesifik enerji değerleri elde edilmiştir. Bu deneyler sonucunda elde edilen verilere blok numuneleri ve endüstride kullanılan elmas soket kompozisyonu için optimum kesme parametreleri belirlenmiştir.

Anahtar kelimeler: İzolasyon Blok, Kesme Performansı, Elmas Soketli Dairesel Testere, Kesme Kuvvetleri, Güç Tüketimi, Spesifik Enerji

1. Introduction

Pumice is a porous volcanic rock with amorphous structure and composed mainly of SiO_2. In chemical terms, silica constitutes up to 75% of the pumice content. Pumice has macro and micro-size pores and a hardness value of 5–6 (Mohs) and specific density of 1.0–2.0 g/cm^3. Since the pores are generally unconnected with and distant to each other, pumice has low permeability and high thermal and sound insulation capacity. Due to these advantageous physical characteristics, pumice is widely used in many industries [1]. Main pumice deposits in Turkey are found in Nevs¸ehir, Kayseri, Bitlis and Isparta Regions, with a total reserve of nearly 3 billion m^3. There are two types of pumice: acidic and basic pumice. Acidic pumice was used in this study since it is widely found in Turkey [2]. Using low-density and high-porosity pumice instead of the usual aggregates is possible. These usual aggregates include broken stones and sand/pebbles, which are used in the concrete to manufacture lightweight building components (isolation blocks or isolation bricks); such components comprise 60% to 80% concrete [3-5]. The manufacturing process is performed in several steps, as follows: classification of the pumice into suitable dimensions; pouring into molds after mixing with appropriate measurements of cement and water; shaping by vibrated pressing process; and curing, packaging, and obtaining the finished product after manufacturing [6]. The lightweight block components for a single row of porous wall is produced by initially using a block cutting machine with a circular saw to produce the isolation block. The following changes were made via the classical production process: (i) using much larger molds instead of small-sized molds; and (ii) instead of pumice block robotic production process (vibration and pressing), dimensional isolation blocks were obtained by using a block cutting machine with a circular saw, which is used in cutting the products produced in blocks and natural stone blocks [7,8]. In the block cutting machine with circular saw, cutting discs in different dimensions are selected. On the tips of these cutting discs, diamond sockets in different shape and compositions are used. The convenient selection of these diamond sockets for cutting the sample affects the cutting process significantly. Other factors that affect the cutting process include peripheral speed, progress speed, cutting depth, cutting breadth, diameter of the saw, and water flow. Selection of the convenient socket and cutting parameters for the sample to be cut can affect the efficiency of cutting, electricity consumption, and cutting cost. Therefore, the convenient selection of the diamond sockets and sample cutting parameters is important [9]. Various studies on diamond sockets have been published. These studies generally focused on the following: erosion of diamond sockets during the cutting of rocks and concrete; cutting performance of diamond sockets; cutting forces (Fc), specific energy (SE), power consumption (P), and damage on the diamond sockets; and determination of the convenient composition of diamond sockets for the sample cut. Circular saws where diamond sockets are fitted have also been studied. Literature information on the dynamic behavior and cutting methods of circular saws is available. In addition, analytical studies on the design of diamond sockets and the modeling and identification of the Fc are also available [10-30].

Studies have been performed on several issues, such as cutting force occurring in circular saws depending on the physico-mechanical properties of rocks, modeling of specific energy and socket, definition of the theoretical chip geometry, and connections between tangential cutting force and chip thickness. In determining the specific cutting energy and power consumption, the effect of processing parameters on tool wear, the modeling of natural stone cutting with diamond cutting tools, and the association with the specific grinding energy of chip samples under a scanning microscope have been examined[31-56].

In the present study, cutting experiments were performed using a cutting machine with a fully automated, computer-controlled circular saw. A single type of concrete block sample and a single type of diamond socket were selected, and variation experiments were performed using different cutting parameters. The P, Fc, and SE data were obtained from the results of these experiments. The optimum cutting parameters for the performance experiments of four kinds of lightweight concrete block samples were determined using the data from the variation experiments. Vital information was obtained for increasing the efficiency of producing isolation blocks by using pumice aggregated lightweight concrete.

2.Material and Method

2.1. Material

In this study, the pumice from which the properties will be developed and used in the mixture of Lightweight concrete was obtained from the acidic pumice in the Nevşehir area (Hilal Bims, Ltd.). The cement properties of the pumice aggregate used in this study are provided in Table 1.

Pumice Properties	Unit	Values
Color	-	White
Mohs hardness	-	6
pH	-	5,5-6,0
Specific gravity	kg/m^3	2320,0
Dry bulk density	kg/m^3	423,0
Water absorption	%	34,0
Compactness ration	%	18,5
Real porosity	%	69,0
Visible porosity	%	81,5
Pumice Insulation Property		
Thermal conductivity	W/mK	0,132
Plaster holding	-	Very good
Specific heat capacity	kcal/kg°C	0,255
Sound conductivity coefficient		0,20
Cement Property		
Specific gravity	kg/m^3	3100,0
Compressive strength 28-day	MPa	43,00

Table 1. Technical properties of pumice and cement [7,8]

2.2. Industrial Production Method of the Isolation Block

The isolation block was cut in a modern automatic block cutting machine that was adapted from the natural stone sector with the proper dimensions (Fig. 1a). In the cutting machine with a circular saw, two vertical saws were used to perform multistage cutting, instead of one vertical and one horizontal saw in the natural stone sector. Initially, the small-scale vertical saw cut half of the block's stage at 650 mm height, and subsequently, the large-scale saw cut the other half (Fig. 1b). Large slices of 1,250 mm × 650 mm × 200 mm blocks were obtained after processing by the block cutting machine with a circular saw. These large blocks were obtained from the production band using a vacuum robot machine (Fig. 1c). Initially, the large slices of blocks were cut in the 1,250 mm × 200 mm × 200 mm dimension by using a height dimensioning machine. Subsequently, the blocks were cut in the 200 mm × 400 mm × 200 mm dimensions by using a breadth-dimensioning machine; in total, 54 isolation blocks were produced from a large block (Fig. 1d and Fig.2) [7,8].

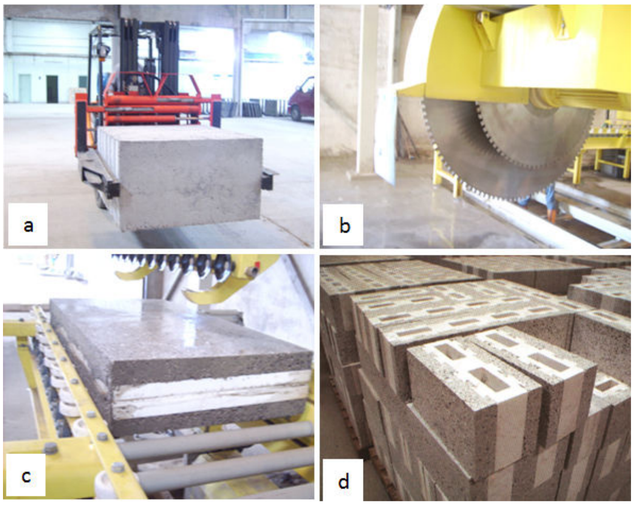

Figure 1. Process in the production facility of isolation blocks [7,8]

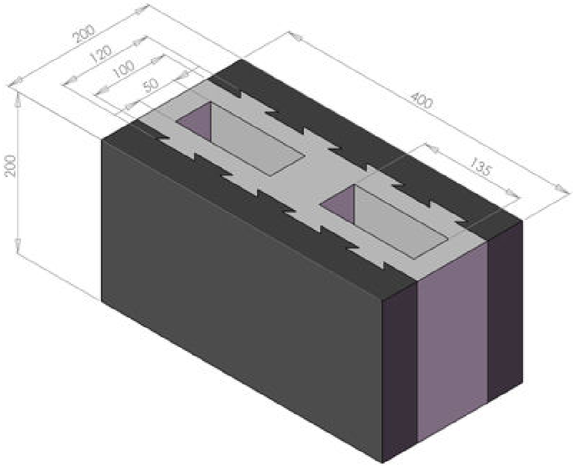

Figure 2. Cutting modelling of the insulation block in automatic cutting unit[7,8]

Inner face of the insulation block was polystyrene foam with average thickness of 110 mm and each outer face was lightweight concrete plate with average thickness of 45 mm (Fig. 3).

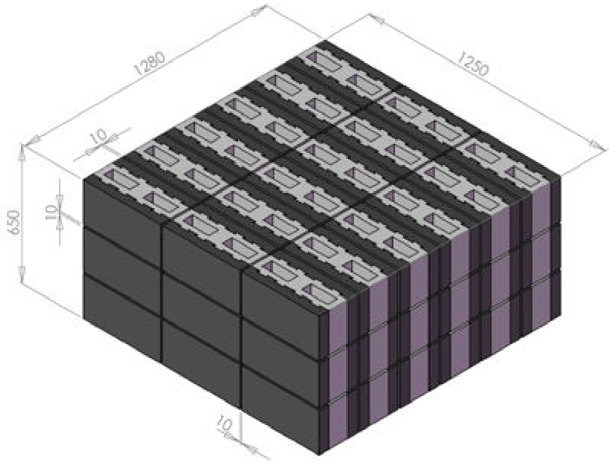

Figure 3. Dimensioning symbols and representations used for insulation block[7,8]

Flow chart of the production of classic bimsblock and new insulation block are given in Fig. 4. The insulation block was designed to utilize pumice, cement and EPS (polystyrene foam) to produce a new construction material with high thermal and acoustic insulation.

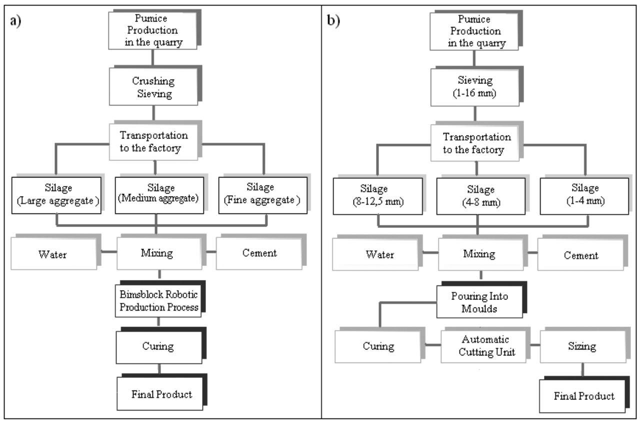

Figure 4. Flow chart of insulation block production method[7,8]

2.3. Samples of the Lightweight Concrete Blocks Used in the Experiments

The lightweight concrete block samples used in the experiments were obtained from IZODUO Company. The general mixture rates and properties of the samples are provided in Table 2.

Materials	Concrete block samples	Mixture Material	Ratio (%)	N	Dimensions (mm)
Lightweight Concrete Block	C1 C2 C3 C4	Pumice Aggregate Cement Water	70-75 8-15 15-20	6	200*600*150

Table 2. Properties of the lightweight concrete block samples used in the experiments

The lightweight concrete block samples were special mixtures of IZODUO Company. Chemical analysis results of the concrete block samples obtained from Eskisehir region are listed in Table 3.

Chemical analysis	Unit	Concrete block samples			
		C1	C2	C3	C4
SiO_2	%	43,66	46,49	48,07	43,64
Al_2O_3	%	9,42	10,91	11,33	9,12
Fe_2O_3	%	2,05	1,61	1,91	1,97
MgO	%	0,94	0,83	0,88	0,95
CaO	%	23,08	21,10	20,03	24,37
Na_2O	%	1,80	2,16	2,00	2,01
K_2O	%	2,23	2,57	2,45	2,40
TiO_2	%	0,23	0,20	0,20	0,23
P_2O_5	%	0,04	0,04	0,04	0,05
MnO	%	0,05	0,05	0,05	0,05
Cr_2O_3	%	0,013	0,004	0,010	0,010
Ba	ppm	254	255	259	244
Ni	ppm	112	68	87	110
Sr	ppm	163	151	155	174
Zr	ppm	96	95	94	100
Y	ppm	14	16	15	14
Nb	ppm	10	14	13	<5
Sc	ppm	4	4	3	4
LOI[a]	%	15,6	14,0	12,3	15,1
Total	%	99,19	100,01	99,36	100,02

Table 3. Chemical analysis of concrete block samples

2.4. Cutting Experiment Mechanism

Computer-controlled side-cutting machines were used as cutting experiment mechanisms. The experiments were performed using the side-cutting machines at the Technology Research Center of Afyon Kocatepe University. The design, production, and modernization of this machine were realized within the scope of various projects [57-59]. The general appearance of the cutting machine with a circular saw is shown in Fig. 5.

Figure 5. General appearance of the cutting machine with a circular saw

A circular saw with a maximum diameter of 400 mm can be fitted onto the machine. The rotational movement of the saw was controlled by an electric engine with a 5.5 kW and 3,000 cycle/min alternating current. All the controls for movements, such as in the x-, y-, and z-direction, and the flow of the cooling water, cutting speed, and peripheral speed, were manipulated via computer. The forward–backward movements of the spandrel and the front–back and up–down movements of the saw cap were manipulated using a computer with 0.75 kW AC engines. Limit keys (inductive sensor) were present in the machine to ensure the safety of the worker and to detect the movements to properly operate the machine. The schematic diagram of the machine is provided in Fig.6.

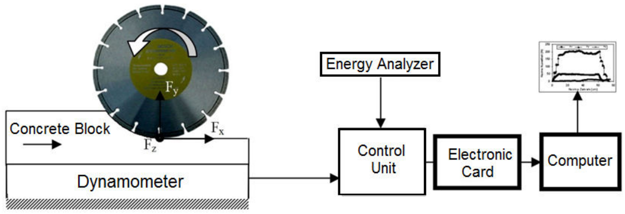

Figure 6. Schematic view of the cutting machine with a circular saw [61]

P values during the cutting were determined through the SHARK 100 energy analyzer. The measurements of the forces in the x-, y-, and z-direction were performed during the cutting, which was done using an ESIT brand dynamometer. This dynamometer can measure the Fx, Fy, and Fz forces simultaneously [60]. A three-direction dynamometer and an energy analyzer were used to obtain the data from the cutting machine with a circular saw, which was connected to a control unit. The control unit was connected to a computer, and everything was computer operated. A power control unit, electronic cards, and a special software were used for machine automation. Different parameters, such as the peripheral speed, progress speed, cutting depth, cooling liquid flow, and cutting breadth, were necessary for the cutting process; these parameters were designed by entering the parameters into a special software in the computer [61]. We used a software interface where the data obtained from the dynamometer and energy analyzer were collected. From this interface, both sets of data were collected, and the movements of the machine were controlled.

2.5. Properties of the Diamond Cutting Disc

In the cutting experiments, the preferred circular saws in the concrete cutting industry were used. The geometrical properties of the cutting sockets used in the variation and performance experiments are presented in Table 4. Circular saws with a 400 mm diameter (D) diamond socket and a 2.5 mm disc breadth (T) were used in the experiments.

Sockets in Circular Saw	Socket Length (mm)	Socket breadth (mm)	Height (mm)	Number of diamond socket in circular saw
S1	24	7	12,5	28

Table 4. Geometric properties of the circular saw sockets.

2.6. Experimental Parameters and Calculations

The different cutting parameters were determined in the variation experiments by considering the cutting parameters suitable for the power of the machine. Such parameters were used in industrial concrete cutting (Table 5).

Cutting Speed (m/min)	Peripheral Speed (m/s)	Cutting Depth (mm)
1 – 1,5 – 2	40 – 60 – 70 – 80	50 – 80 – 110

Table 5. Cutting parameters used in the various experiments

The variation experiments were performed using these cutting parameters. Each experiment was repeated thrice to obtain reliable and correct results. Water was used as a cooling liquid at a density of 15 db/min.

The performance experiments were conducted by using four types of concrete block samples, and the composition of the diamond socket was used to cut the concrete blocks in the industrial environment. The equation Qw = 600*110*7 = 462,000 mm^3 was used. Based on this equation, the peripheral speed was obtained at 60 m/s, the progress speed was 2 m/min, and the cutting depth was 110 mm. The experiment on each concrete block was repeated 20 times to obtain the correct results.

By utilizing the data obtained from the variation and performance experiments, the SE, Fn, Fc, and Ft were calculated. The values for Fx and Fy were obtained from the experiments, whereas the Fc was calculated using the following equation:

$$\mathrm{Fk} = \sqrt{\mathrm{Fx}^2 + \mathrm{Fy}^2} \quad (1)$$

The Ft was calculated using the following equation, which also included the P and the peripheral speed of the circular saw.

$$\mathrm{Ft} = \frac{\mathrm{P}}{\mathrm{Vc}} \quad (2)$$

The Fn was calculated using the following equation, which also included the Fc and the Ft [59].

$$\mathrm{Fc} = \sqrt{\mathrm{Fn}^2 + \mathrm{Ft}^2}. \quad (3)$$

The amount of SE was calculated with the following equation using the machine's P, cutting time (t), and volume of wood chips from the concrete block sample (Qw) [60].

$$\mathrm{SE} = \frac{\mathrm{P*t}}{\mathrm{Qw}} \quad (4)$$

A schematic indication of the forces that occurred during the cutting of the concrete block sample is presented in Fig. 7.

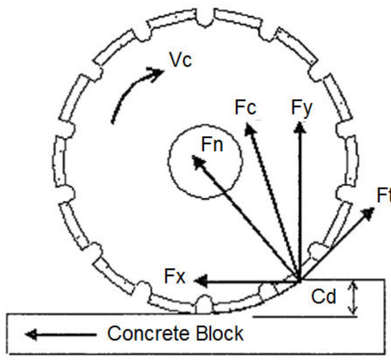

Figure 7. Schematic indication of the forces that were present during the cutting [62]

3. Results and Discussion

3.1. Variation Experiments

In this study, experimental and theoretical examinations were performed. We considered the diamond socket used for cutting concretes in the industry and the various cutting parameters of the four different concrete block samples. In the experimental studies, variation experiments were initally implemented by using the circular saw with a diamond saw and the C1 concrete block sample. In the variation experiments, the Fc and P values were obtained during the cutting process. However, the values of the SE were calculated by using the P values. The volume of the wooden chips was generated from the concrete block sample. The cutting depth showed the greatest effect on the cutting parameters. The Fc and the P value increased with increasing cutting depth. The peripheral speed showed the lowest and highest effects on the P and the Fc, respectively (Fig.8).

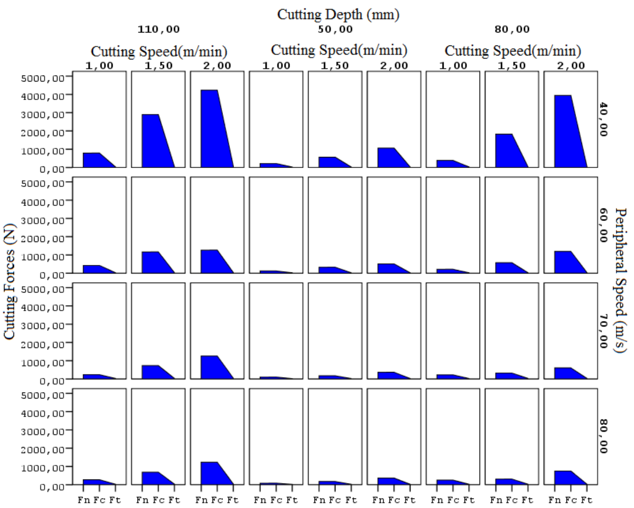

Figure 8. Alteration of the P at peripheral speed, cutting speed and cutting depth.

Therefore, when cutting concrete block samples with a circular saw, a peripheral speed value of lower than 60 m/s (according to the Ft and Fn) should not be selected. The optimum cutting parameters for the performance experiments were selected based on the SE because the SE showed efficiency in the cutting process. The lowest cutting parameters from which the amount of SE was obtained indicated the best cutting efficiency (Fig. 9).

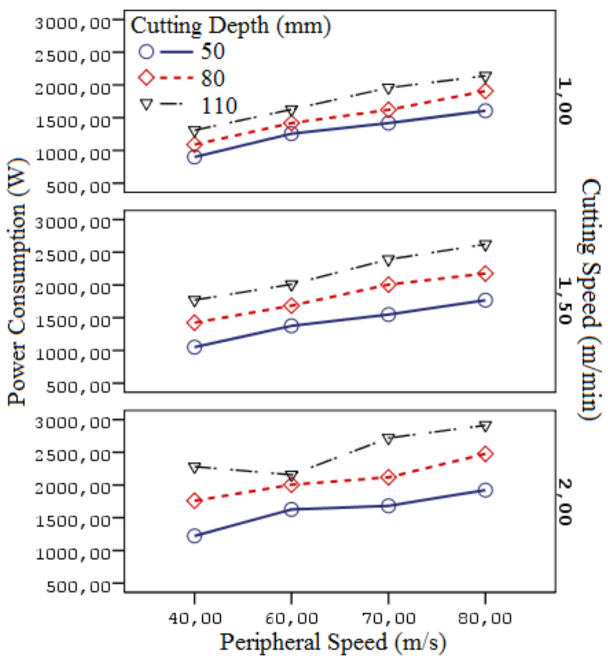

Figure 9. Alteration of the SE at peripheral speed, cutting speed and cutting depth.

The best cutting efficiency was obtained from the cutting parameters where the peripheral speed was 60 m/s, the cutting speed was 2 m/min, and the cutting depth was 110 mm (Fig. 10). These cutting parameters were used in the performance experiments.

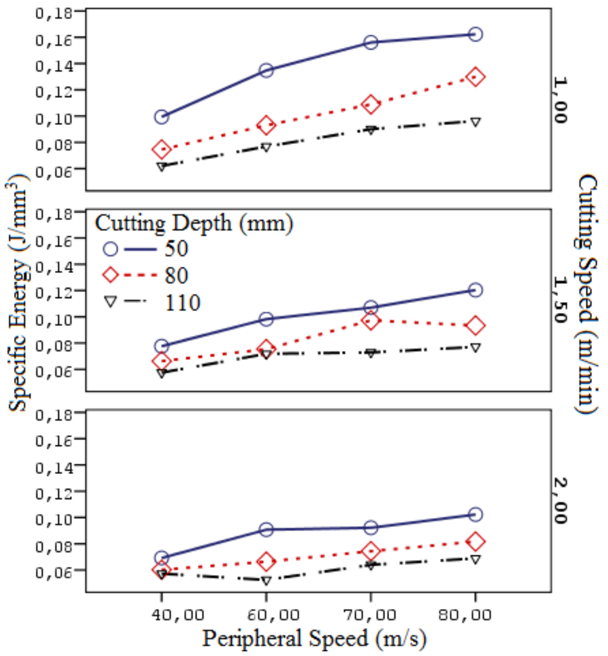

Figure 10. Alteration of the Ft, Fn, and Fc at peripheral speed, cutting speed and cutting depth

3.2. Performance Experiments

3.2.1. Determination of the power consumption

The power consumption (P) of the machine during cutting the four types of concrete block samples with a circular saw was examined. P alteration, which depended on the different concrete block samples, is presented in Fig. 11.

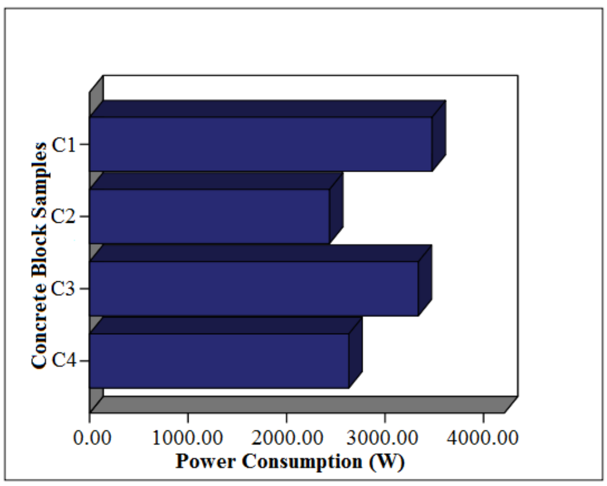

Figure 11. Alteration of P, depending on the concrete block samples

The highest value for P was measured during the cutting of the C4 concrete block sample, whereas the lowest value for P was measured during the cutting of the C3 concrete block sample. The C4 concrete block sample had the highest P value. The

C2 concrete block sample showed a P value similar to that of the C4 concrete block sample. The P values in the cutting process of the concrete block samples directly affected the production cost. The C3 concrete block, which had the lowest P value, also showed the lowest production cost.

3.2.2. Determination of cutting forces

The cutting forces (Ft, Fn, and Fc) values obtained for the concrete block samples are shown in Fig. 12.

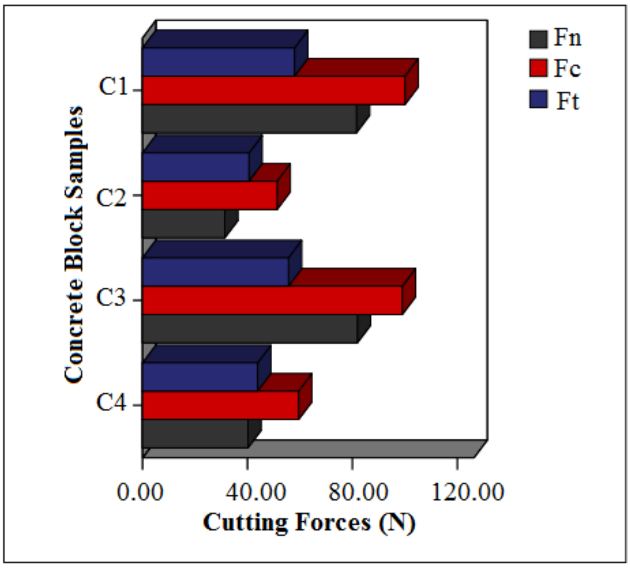

Figure 12. Alteration of the Ft, Fn, and Fc depending on the concrete block samples

The highest Ft and Fc values were obtained from the C4 concrete block sample. The highest Fn values were observed from the C2 and C4 concrete block samples. However, the lowest Fn, Ft, and Fc values were observed from the C3 concrete block sample. The cutting process was performed easily on the C3 concrete block sample. The Ft values were high in the C2 and C4 concrete block samples. The circular saw hardly carried wooden chips at the given cutting depth.

The Ft/Fn values for the concrete block samples are presented in Fig. 13. The Ft/Fn rate provided important information on the cutting process. This rate was inversely proportional with the Fn and was directly proportional with the Ft. The rate of the Ft/Fn decreased with increasing Fn, whereas Ft/Fn rate increased with increasing Ft. A decrease in the Ft/Fn rate indicated the difficulty of the cutting process. The presence of wooden chips during cutting with a low Ft/Fn rate indicated that the chips were not removed from the cutting area and that the friction was high between the concrete block sample and the circular saw. When the cutting of the concrete block samples were assessed according to the Ft/Fn rate, the easiest cutting process was observed with the C3 concrete block sample, whereas the most difficult cutting process was observed with the C2 concrete block sample.

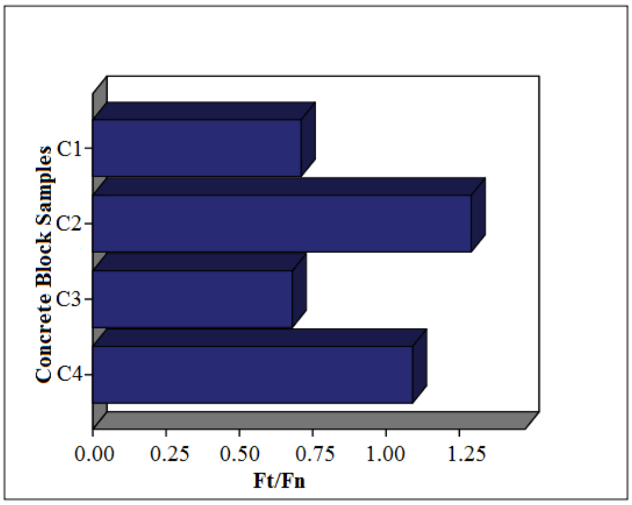

Figure 13. Alteration of the Ft/Fn depending on the concrete block samples

3.2.3. Determination of the specific energy

The specific energy (SE) values obtained from the performance experiences in the different concrete block samples are presented in Fig. 14.

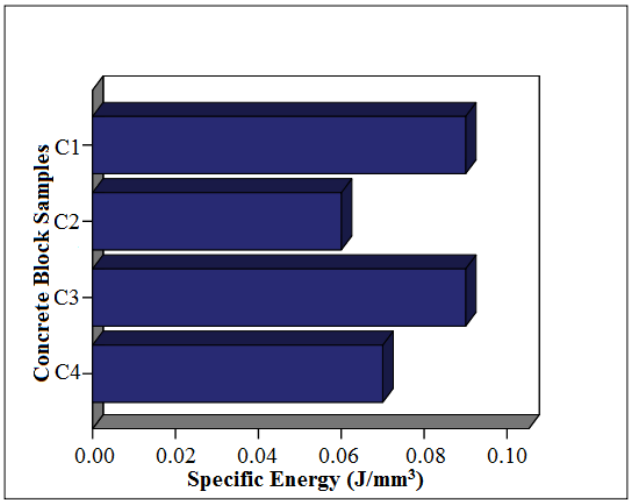

Figure 14. Alteration of the SE depending on the concrete block samples

The highest amount of SE was measured in the cutting of the C4 concrete block sample. The lowest amount of SE was obtained in the C3 concrete block sample. The SE values obtained during the cutting of the C1 and C2 concrete block samples were between the amounts of the SEs of the C3 and C4 concrete block samples. When the SE amount was at the lowest value, the most efficient cutting process value was obtained. The most efficient cutting process was observed with the C3 concrete block sample.

4. Conclusions

The P, Fc, and SE were obtained in the performance experiments. According to the obtained results, the following conclusion were generated:

- The C3 concrete block sample was the easiest to cut at the given SE amount, Fc, and P values. Hence, the lowest production cost was obtained when C3 lightweight concrete block sample was used.
- The lowest Fn, Ft, and Fc values were obtained by using the C3 lightweight concrete block sample. Thus, the cutting process was easy when the C3 lightweight concrete block sample was used.
- The Ft values were high with the C2 and C4 lightweight concrete block samples. Thus, the circular saw hardly carried wooden chips in the cutting depth for these samples.
- The highest Ft/Fn rate during the cutting process was observed with the C3 concrete block sample. Given the Fc values and Ft/Fn rate, the cutting process was easily completed when the C3 concrete block sample was cut with the diamond socket circular saw.
- Given the Fc, SE, and amount of socket erosion, the cutting process of the C3 concrete block sample with the industrial diamond socket composition was completed most efficiently.

Acknowledgments

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