Efficiency analysis of armed-chained cutting machines in block production in travertine quarries

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Synopsis

This study analyses the results of a pilot trial of a newly developed armed-chained stone-cutting machine. The machine was developed in Turkey and trialled at the Kaklık/Kocabaş travertine quarries in the Denizli District. An armed-chained cutting machine is an alternative to the diamond wire cutting method more frequently used in the production of natural stone quarry blocks, and increases production efficiency and quality. Since there is no need to collapse the blocks using the armed-chained cutting production process, there is no risk of the block developing cracks. This results in a considerable increase in the efficiency of natural stone block production. The armed-chained cutting machine is easier both to assemble and run when compared to other block cutting methods. This process resulted in the production of a larger number of blocks at a lower cost within the same time frame, particularly in travertine quarries and in all other natural stone quarries. The block efficiency in travertine quarries was calculated as 65–80% using the armed-chained cutting machine, compared with 7–14% using the normal diamond wire cutting method.

Keywords
Armed-chained cutting machines, travertine quarries, block production, diamond wire cutting, block efficiency.

Introduction

Many different technologies are utilized in block production in natural stone quarries; however, production quality and block efficiency vary due to the features of the natural stone deposit, the cutting method, and cutting machine. Working conditions in natural stone quarries are difficult. Many occupational accidents occur in block production using the standard diamond wire cutting method, when the sequential wires of the cutting edge break, or during the collapse of blocks. Despite all the precautions taken during the collapse of the blocks, blocks may develop cracks, particularly in travertine natural stone, which, in turn, reduces production efficiency. The diamond wire cutting method is widely used in natural stone quarries, and has a block efficiency of 7–14%.

The armed-chained cutting machine can be used in the extraction (in the form of blocks) of low and mid-level abrasive soft natural stones, such as marble and travertine, from both open quarries and underground quarries. This machine can also be used in the block sizing process. The armed-chained cutting machine can further increase quarry efficiency when used together with a diamond-beaded wire cutting machine. The use of a chained cutting machine in addition to a diamond-beaded wire cutting machine can result in a 20% increase in the general efficiency in an open travertine quarry. This efficiency increase results from the advantages provided by the armed-chained cutting machine. When used together with the diamond-beaded wire cutting machine, particularly at steps higher than 6-7 m, the armed-chained cutting machine reduces the number of the holes required to reeve wire in such way as to ensure time and labour savings in natural stone quarries. Hole overlap problems encountered in natural stone quarries are therefore minimized. An armed-chained cutting machine can easily initiate both vertical and horizontal entry into a new step and eliminates the process of cutting triangular pieces. Therefore, this process reduces production and time losses. The process can produce directly salable products. Since it produces considerably smoother surfaces than other production methods, it provides an improved working environment (Çopur *et al*., 2006; Çopur *et al*., 2007a; Çopur *et al*., 2007b; Çopur *et al*., 2008).

Water channels that are naturally present in natural stone complicate the process of efficiently obtaining blocks from main reserve rock in travertine quarries. When one uses a diamond wire cutting machine, blocks are obtained from the reserve rock via collapsing. This large mass of collapsed rock develops cracks emanating from its internal water channels, which results in block loss. Therefore, it was proposed to use an armed-

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chained cutting machine in order to maximize efficiency and minimize loss in block production. As a result of the use of armed-chained cutting machines in quarries, more efficient production will be ensured, with fewer workers; the risk of occupational accidents during the production phase will be minimized; and complex processes applied during the production phase will be eliminated.

Important changes have been recorded in block production methods. Production using an armed-chained cutting machine provides a considerable increase in natural stone block efficiency. Compared to other block cutting methods, an armed-chained cutting machine is easier to both assemble and run. Thus, the use of this machine, particularly in travertine quarries and other natural stone quarries, enables production of more blocks at lower cost within the same time frame. The present study, in a travertine quarry, recorded block efficiency of 65–80% using an armed-chained cutting machine.

The present study presents the first results of a project supported by the TÜBİTAK–1507 SME R&D Initial Support Program. It is expected to provide information that can increase the efficiency of an armed-chained cutting machine (DZK–3400) used for block extraction in natural stone quarries, and that can contribute to technological innovations related to this type of cutting machine. The findings of this project may therefore contribute to the more efficient utilization of natural stone reserves.

Parameters affecting armed-chained cutting machine performance

Many parameters affect the block cutting methods adopted in natural stone quarries. These factors must be analysed in order to obtain blocks with the highest possible efficiency and at the lowest possible cost.

The performance of both armed-chained and diamond wire cutting machines is dependent on the geological and geotechnical features of the quarry, the (mechanical) features of the machine used, and the operating parameters of the quarry. Geological and geotechnical parameters include mass features of the quarry and physical and mechanical features of the natural stone. Mass features of the quarry are comprised of parameters such as the number and range of crack sets, the direction and slope of the quarry, bedding, and foliation. Cuttability features of the natural stone include mechanical strength features (pressure, shrinkage, elasticity module, etc.), physical features (hardness, specific weight, porosity, water absorption, etc.), abrasiveness, mineralogical composition and texture, alteration level, and discontinuities in the natural stone. Operating parameters include the cutting depth, cutting angle, cutting length, rotational speed of the chain, wire speed, structure of the diamond-beaded wire, dry and wash cutting, horizontal and vertical cutting, lubrication, quality and availability of workforce, and availability of materials (Çopur *et al*., 2007a; Çopur *et al*., 2007b).

The mechanical parameters of the machine include power-torque-stress capacity, machine vibration, arm length, cutting width, sequence of chasers on the chain and metallurgical and geometric features of chasers. Qualified personnel and the techniques adopted in the scope of block cutting methods affect the operating conditions (Çopur *et al*., 2007a; Çopur *et al*., 2007b).

Material and method

Material

Technical features of Denizli travertine

The natural rock samples used in the present study were collected from the Kocabaş travertine quarry operated by DEMMER A.Ş in the Kaklık District of Denizli Province, Turkey. The volume mass test, specific mass test, water absorption test, single-axes compressive strength test, and permeability test were conducted to determine the physical-mechanical features of Denizli travertine. Samples were prepared for a single-axes compressive strength test (in 70x70x70 mm size) and for a permeability test (30 mm in diameter and 50 m in height). Tests were conducted on 5 samples according to TS EN 1936, TS EN 1926, DIN EN 18130-1 standards respectively. Chemical analysis of Denizli travertine was carried out in ACME/Canada Analytical Laboratory via the XRF (ICP-MS) method. Chemical analysis indicated that the travertine included 51.4% CaO. Chemical and physical-mechanical features of the tested Denizli travertine are shown in Table I.

The mean grain size of Denizli travertine varied between 30 and 100 microns for the sparitic calcite and between 1 and 4 microns for the small amount of micritic calcite minerals present in the travertine. The travertine had a porous structure. These pores are considerably larger than the pores of other types of stone, and characteristic of this type of travertine. Analysis of the travertine sections revealed calcite crystallizations around the pores (Figure 1). It was observed that this crystallization developed in proportion to the time elapsed and that, in some cases, they encircled only the pores. In this group of travertine, in-rock filling is generally micritic. There are also some travertines which have a clayey view as well.

Table I

Chemical and physical-mechanical features of Denizli travertine (Sariisik, 2007)

Compounds	wt %
SiO_2	0.26
Al_2O_3	0.08
Fe_2O_3	0.04
MgO	0.42
CaO	54.1
Na_2O	<0.05
K_2O	<0.01
TiO_2	<0.01
P_2O_5	0.01
MnO	0.01
Loss of ignition	44.0
Total	100
Specific mass (g/cm^3)	2456
Unit volume weight (g/cm^3)	2150
Water absorption by weight (%)	5.43
Water absorption by volume (%)	11.68
Porosity (%)	12.46
Permeability (strength (Mpa)	18.89
After-frost compressive strength (Mpa)	17.79
Wear resistance (cm^3/50 cm^2)	9.70
Bending strength (Mpa)	11.60

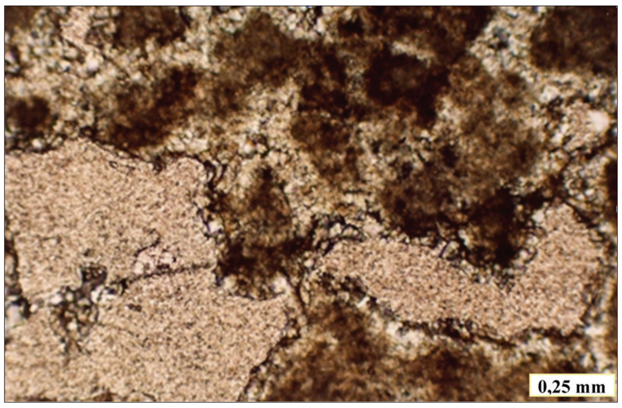

Figure 1—Calcite structure developed around lime mud, (X 10, Tek Nikol)

The Kaklık-Kocabaş (Denizli) Travertine quarry is composed of layer-type travertine deposited on horizontal or nearly horizontal surfaces by water containing calcium-bicarbonate, generally at a high flow rate over a huge area (Ayaz and Gökçe 1998). Demirkıran and Çalapkulu (2001) stated that, in morphological classification, the travertine type that occurs in lacustrine areas differs not only from other travertine types (since it is composed of quite smooth surfaces and there are regular gas spaces between the layers) but also from lacustrine limestone (since plant fossils are rarely encountered and it has no other fossil component). Since Denizli travertine quarry is a closed-type quarry, the cutting process is carried out along with water channels. This type of cutting is performed in parallel with the bedding/schistocity or flow structures. To obtain a block cut along with the water channel, cutting is performed vertically to the layer direction or along the slope direction. Bedding is observed along the long side of the block (parallel to bedding/schistocity).

Machines and technical features

Armed-chained cutting machine

An armed-chained cutting machine is used to obtain blocks with a smooth geometrical structure in marble and travertine quarries. The machine is composed of three main parts: arm group, car group, and rail group (Figure 2). The part which wears most and encounters most problems during operation is the arm group. Therefore, important engineering calculations are made to extend the operational life of arm parts. After arm group parts are assembled, the car group is assembled. All parts are assembled in the appropriate sequence and *in situ* checks are made. In the last phase of production, the rail group is assembled. Armed-chained cutting machines are manufactured to varying specifications, and are individually designed to meet the operational requirements of specific rock types or quarry locations. Once assembled, they are subjected to post-production efficiency tests. After establishing that all parts meet the required efficiency criteria, the machine is permitted to be used in the natural stone quarries.

Replaceable cutting edges are mounted on the chain rotating around the steel alloy arm, specifically produced for the cutting process. The surfaces of these cutting edges are subjected to a special process to ensure maximum wear resistance (Figure 3).

This chained arm is used to smoothly size marble and travertine blocks while they are still attached to the main rock and to separate these blocks from the main rock. The cutting thickness using an armed-chained cutting machine is 42 m. This cutting thickness enables problem-free functioning of the machine within the desired cutting range.

The arm and the carbide-based cutters on the arm are the machine parts which wear most and which are used most. Cutting edge sequences are designed specifically to ensure maximum cutter efficiency (Figure 4 and 5). 99 diamond cutting edge katers and 126 titanium-coated carbide cutting edges are mounted on the chain body of the machine. Cutting edges constitute a square prism with 13.2 mm side length and 6 mm thickness, eight sides of which can be used (Figure 4).

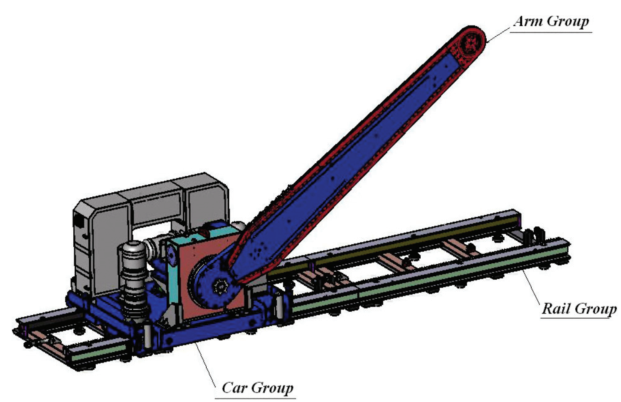

Figure 2—Parts of armed-chained cutting machine

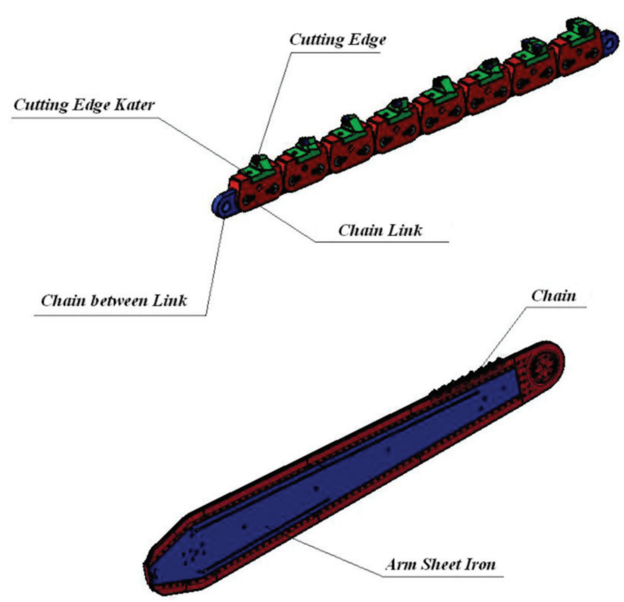

Figure 3—Arm group of armed-chained cutting machine

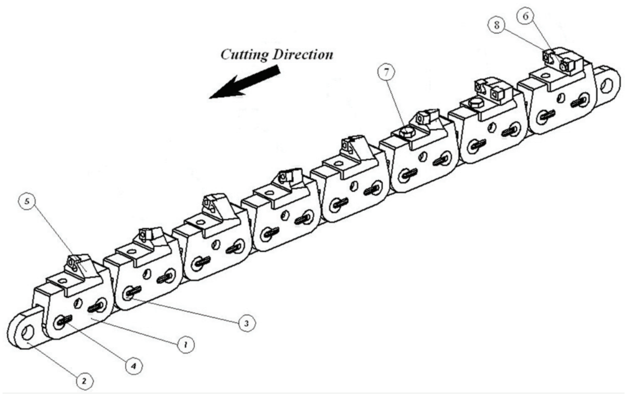

Figure 4—Chain body of the armed-chained cutting machine (1) chain body. (2) link. (3) pin. (4) joiner pin. (5) cutting edge kater. (6) M5x16 wrench bolt connecting cutting edge to kater. (7) M8x15 wrench bolt connecting kater to chain body. (8) Carbide cutting edge

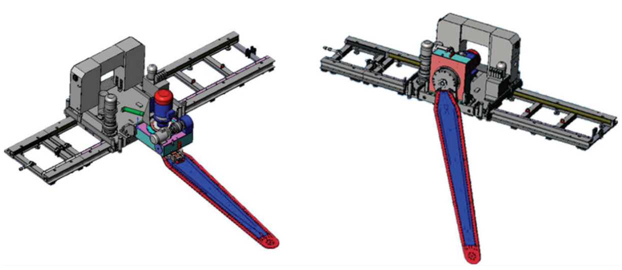

Figure 5—Car and rail group of the armed-chained cutting machine

The reducer box driving the arm group can be rotated 90º by a hydraulic cylinder, and the armed-chained cutting machine can perform horizontal and vertical cutting procedure on the main reserve rock. The arm produced from a special steel alloy can be removed easily, allowing arms of different sizes to be used. Depending on the arm length, an armed-chained cutting machine can perform cutting procedures in depths of 2.0–7.4 m.

Cutting processes change according to the type of natural stone; however, the mean feed rate is 3 m/h. During the cutting process, the machine moves on a rail. By extending the rails, a continuous cutting process can be performed. Armed-chained cutting machine and rails can be easily transported by the duty vehicles in the quarries. Transportation is assisted by the carrying apparatus on the machine. The technical features of the armed-chained cutting machine used in the pilot trials are listed in Table II.

Diamond wire cutting machine and its technical features

A diamond wire cutting machine uses an abrasive diamond wire, wound around a drum on the machine, to cut the rock. The machine can perform vertical and horizontal cutting processes. The machine moves backward, generally on 6–8 m long rails, in such way as to exert the pressure required for the cutting process. During this process, the diamond wire is rapidly rotated by the motor-driven drum to perform the cutting process. The diamond wire cutting machine used during the pilot trials is shown in Figure 6 and its technical features are listed in Table III.

Method

Natural stone block production methods

Methods adopted in the production of natural stone blocks are classified into two groups: manual or primitive tool methods (canalization, hole drilling, explosives) and mechanical methods. Newly developed mechanical methods have become most common: diamond wire cutting, diamond belt-armed cutting, and armed-chained cutting methods.

Table II

Technical features of Demmak ZK-3400 armed-chained cutting machine

Main starting motor of the chain	37 KW (50 HP)
Machine running engine	2.2 KW (3 HP)
Arm rotating engine	2 KW (3 HP)
Hydraulic power unit engine	3 KW (4 HP)
Lubrication pump engine power	0.37 KW (0.5 HP)
Total engine power	45 KW (60 HP)
Rail length	9.1 m
Chain arm length	3.40 m
Cutting thickness	42 mm
Cutting speed	0–18 cm/min
Chain speed	0–1.5 m/s
Machine weight	8100 kg

Figure 6—Diamond wire cutting machine

Table III

Technical features of Demmak TKE-50 diamond wire cutting machine

Diamond wire cutting machine TKE–50 DEMMAK)	
Engine power	37KW, 50HP
Running engine power	1 HP
Drum diameter	80 cm
Drum turnover	900 d/d
Wire rotation capacity	80-100 m
Wire type	Diamond
Cutting thickness	11 mm
Cutting speed	8–12 m^2/min
Operation angle	360°
Rail length	6 m
Water requirement	8–12 ℓ/ d
System type	Automatic

Efficiency analysis of armed-chained cutting machines in block production

Diamond wire cutting method

In the diamond wire cutting method, firstly, holes are drilled to start the block production process. Discontinuities in the marble or natural stone, from which blocks will be produced, determine the block size. In case there are so many discontinuities in the marble, block size should be kept as large as possible. Therefore, it is possible to obtain more than one piece in one cutting process. In blocks free of any structural defect, the hole sequence is determined according to the desired block size. After the block sizes are determined, hole locations are established. Firstly, vertical holes are drilled. The depth of the vertical hole (1) should be equal to the step height (4–5 m). Then, two horizontal holes (vertical to each other) are drilled (2), and these three holes are superposed (3) (Figure 7a). After the holes are drilled and superposed, diamond wire is passed through the horizontal holes to start the cutting process. The diamond wire cutting machine is positioned in the horizontal direction to the perform horizontal cutting process. Then, the vertical cutting is performed in the same way. Thus, the marble block is separated from the main rock (Figure7 b). By using a hydraulic bag or lever jack, block discontinuities (if any) are eliminated (Figure 7c). The gap created as the marble block is separated from the main rock with the help of a hydraulic bag or level jack is supported by placing a deadwood to the gap. In addition, soil hills are formed in the area where the block will collapse, to prevent any cracks in the block when it falls from the main rock. Thus, the block is laid down without any crack formation. Unshaped marble blocks cut and separated from the main rock or large blocks are smoothed by using a sizing machine (Figure 7d). After sizing, the smooth marble blocks are ready for transportation and for further processing at a factory (Özçelik *et al.*, 1999; Özçelik *et al.*, 2002; Demirel, 2008).

Diamond belt-armed cutting method

This is the most recently developed marble cutting method. A diamond belt-armed cutting machine is composed of four parts: car group, cutting arm, rails, and electrical panel board. The cutting principle of the diamond belt-armed cutters is similar to that of armed-chained cutters. However, in this method, the cutting arm is a special belt which rotates at 5 m/s and on which a large number of sintered diamond pieces are mounted. Lubrication and cooling of the belt is ensured via pressurized water (3 atm, 100 ℓt/min flow rate). The cutting range the width of the cut is 40 mm and the cutting depth is in the range 1.7–4.8 m. A diamond belt-armed cutter can perform only vertical cutting processes. Therefore, it is used in formations including horizontal discontinuities or in combination with a machine which can perform bottom cutting (Demirel, 2008).

Armed-chained cutting method

An armed-chained cutting machine is particularly successful in block production in massive natural stone quarries. The production process requires the construction of a series of production steps. First, the location of the chained cutter is determined according to the length of the block to be produced. The main machine is slowly and carefully transferred by a bucket to the appropriate step for the cutting process. The cutter and its rail are positioned parallel to the step surface, with the help of a scale and mounts. To fix the cutter and its rail, 10-cm holes (corresponding to the location of the rail holes) are drilled on the step surface. T-posts are inserted into these holes to fix the cutter. The cutting edges on the cutting arm are checked individually, to replace worn cutters and tighten any that have loosened. Indications of cutting edge wear include increased operating pressure of the chained cutter, increase in the current drawn by the chained cutter, and accumulation of the chippings produced during the cutting process (Figure 8).

Evaluation

Efficiency of block production using an armed-chained cutting machine in travertine quarries

Block production in travertine quarries is the process of

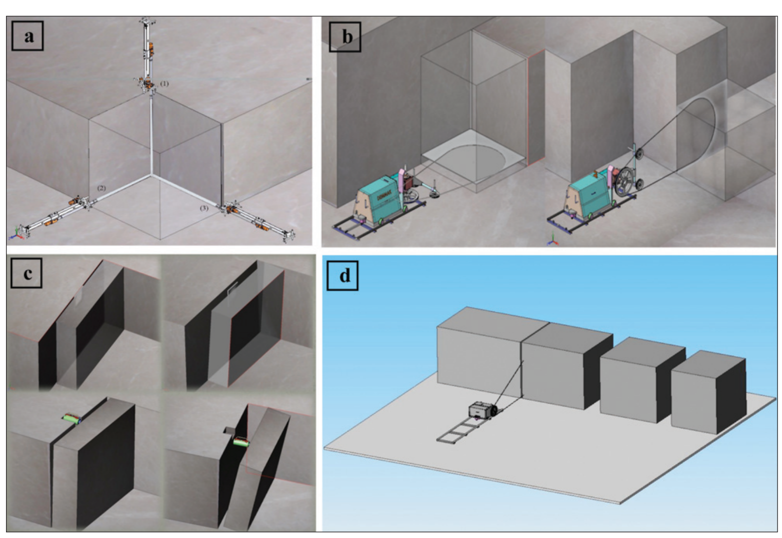

Figure 7—Production via diamond wire cutting method

obtaining 11–12 m blocks from the reserve rock by using a diamond wire cutting machine, pneumatic drilling, and sizing machines. Soil hills are formed along the side of the open surface of the reserve rock, to serve as a buffer during the collapse process; the function these hills is to absorb inertia during the collapse of large blocks from the reserve rock. Despite this buffering process, water channels within the blocks may result in cracks during the collapse process. Due to these cracks, only 15–18% of the main mass can be utilized. Developing a cutting process which minimizes crack formation is therefore a significant factor in the efficient use of this resource. Formation of the sand hills to be used during the collapse process involves excavation. After the collapse process, a second excavating process is carried out to remove these hills. In addition, a further excavation process has to be performed to remove from the site any block pieces which have become unusable during the collapsing process. The purchase and operation of duty vehicles and the energy required for these processes represent significant operational costs (Figure 9).

Figure 8—Production via armed-chained cutting machine

Figure 9—Travertine block collapsing process

Production systems which use wire cutting methods involve high losses of raw materials. The most effective means of minimizing these losses is to size the desired travertine block when still in the main reserve rock and to transport these blocks without using the collapsing method when separating the blocks from the reserve rock. Therefore, the most appropriate method for *in situ* block sizing is the use of an armed-chained cutting machine (Figure 10a). With the help of this machine, it is possible to obtain blocks which are sized and sequenced (when still in the main reserve rock) via parallel and vertical cuts (Figure 10b). When bottom cutting processes of the blocks sequenced by the armed-chained cutting machine are completed, the raw material obtained is ready to transport. Since there is an intermediate clay layer present in the Denizli travertine quarry, there is no need for a bottom cutting process. In such travertine quarries, bottom cutting is performed more easily by using the water channels (Figure 10c). Discontinuities created by water channels in the open surface side of the vertical and parallel sized blocks at bottom cutting level are utilized to separate the blocks from the reserve rock via compressive nails and plastic loader apparatus (Figure 10d).

Figure10—Production via armed-chained cutting machine

Comparison of armed-chained cutting machine and diamond wire cutting machine in travertine quarries

A Demmak TKE- 50 diamond wire cutting machine and Demmak ZK- 3400 armed-chained cutting machine were compared experimentally at the Demmer A.Ş. travertine quarry in Kocabaş region of Kaklık District, Denizli Province, Turkey.

Operating costs, cutting performance, working conditions, block efficiency, occupational safety, and water consumption features of armed-chained cutting machine and diamond wire cutting machine are listed in Table IV and Table V respectively. Considering these data, the armed-chained cutting machine is suggested to be more advantageous than the diamond wire cutting machine.

Table IV

Features of the armed-chained cutting machine used in travertine quarries

Investment cost (in TL)	150 000.00
Total engine power (kW)	48.5
Cutting performance	9 m^2/h
Cutting speed	3 mt/h
Cut surface (cutter carbide)	1000–1200 m^2
Water requirement (for travertine)	None
Working temperature	-15°C / +40°C
Occupational safety	High
Block efficiency	%60–80
Additional block collapsing processes (Fuel consumption, use of duty vehicles)	None
Cutting edge cost	0.7–0.8 TL/m^2

Table V

Features of the diamond wire cutting machine used in travertine quarries

Investment cost (in TL)	
Wire cutting machine	14 000.00
Sizing machine	6 000.00
Pressurized drilling machine	11 500.00
Hydraulic lever jack	6 500.00
Compressor	13 500.00
General total	51 500.00
Engine power (kW)	
Wire cutting machine (kW)	37
Sizing machine (kW)	15
Pressurized drilling machine (kW)	11
Hydraulic jack lever (kW)	4
Compressor (kW)	37
Total engine power (kW)	104
Cutting speed	10–12 m^2/h
Cut surface (1 m diamond wire)	100–200 m^2
Water requirement	Yes
Working temperature	+4°C / +35°C
Occupational safety	Low
Block efficiency	%15–20
Additional block collapsing processes (Fuel consumption, use of duty vehicles)	Yes
Cutting edge cost	0.4–0.5 TL/m^2

Initial investment costs of the armed-chained cutting machine are higher than that of the diamond wire cutting machine; however, the operational lifespan of the former is three times that of the latter.

Climate conditions play an important role in production processes based on a diamond wire cutting system. Low air temperatures result in the freezing of the water used during the cutting process, thereby complicating the production process. In addition, adverse climatic conditions also affect the workforce, thereby reducing efficiency. Water cutting is not required when using an armed-chained cutting machine in the travertine quarries; therefore, production is possible within an air temperature range of -15°C – +40°C. Thus, the eliminating water from the cutting process by using an armed-chained cutting machine enables four-season production in the travertine quarries.

In the scope of this study, the use of a diamond wire cutting machine achieved 7–14% block efficiency, which increased to 80% using the armed-chained cutting machine. Depending on the arm length, the armed-chained cutting machine can cut blocks in depths changing in 2.0–7.4 m range. Since blocks are sized when still in the main reserve rock, wastage of raw materials is minimized. The efficiency of the blocks (completed cutting processes) increased up to 65–80% in the present study. When compared to the values obtained from other cutting methods, the armed-chained cutting machine resulted in 6–11 fold increases in block efficiency. Despite the costs incurred to obtain blocks from travertine quarries were recorded to be same in these two different methods, block unit cost reduced by 6–11 fold in the armed-chained cutting machine.

Since it is easy to mount/dismount the rails used in the armed-chained cutting machine, time loss during production is minimized. Drilling and combining the holes necessary for production by the wire cutting method are not required in the armed-chained cutting method, so no delays are experienced during production. Whereas it takes 110 minutes to start the cutting process in the diamond wire cutting machine, this time is reduced to 90 minutes for the armed-chained cutting machine.

During block production using the diamond wire cutting machine, many occupational accidents occur when the cutting edge sequential wires break and when blocks collapse. It is quite difficult to ensure occupational safety in quarries when using this system. Employers have to deal with many problems, including the aggrieved workers and their families after occupational accidents. The use of an armed-chained cutting machine in block production maximizes occupational safety. Events recorded in wire cutting system (such as wire breaks) do not occur in the armed-chained cutting machine. Since blocks are sized when still in the main reserve rock, there are no cracks on the block and, no dangerous situation that can affect the workers arises. When compared to other block production methods, the armed-chained cutting method is the safest block cutting system in terms of occupational health and safety.

Comparison between domestic (Turkish) and imported armed-chained cutting machines shows that domestic machines are more advantageous than imported ones in terms of investment cost, spare part supply time, and cutting edge consumption (Table VI).

Table VI

Comparison between domestic and import armed-chained cutting machines (Fantini, 2008; Garrone, 2008)

	Demmak	Fantini	Garrone
Domestic/import	Domestic	Import	Import
Investment cost (in TL)	150.000	187.000	161.500
Spare part supply time	3 days	8 weeks	10 weeks
Maximum arm length	3.4 m	6.8 m	7.4 m
Machine operating system	Gear Box	Hydraulic	Hydraulic
Total engine power (kW)	48.5	51.0	50.0
Cutting performance (for travertine)	9–10 m^2/h	9–10 m^2/h	9–10 m^2/h
Cutting edge cost (for travertine)	0.132 Ad/m^2	0.166 Ad/m^2	0.166 Ad/m^2

Conclusions

With a 340-cm arm length, the DZK–3400 armed-chained cutting machine achieved a net cutting speed of 9–10 m^2/h in vertical cuts at 3.2 m height in the Denizli Kaklık Travertine quarry of Demmer AŞ. Average cutting edge consumption in vertical cuts was 0.132 ad/m^2.

The production speed of the armed-chained cutting machine was more than three times that of the diamond wire cutting machine used for comparison. Raw material efficiency increased by 6–11 fold. All work can be carried out using 30% fewer workers. All excavation works required in the diamond wire cutting process are eliminated in the armed-chained cutting process. Whereas block efficiency was recorded as 7–14% in the diamond wire cutting method in travertine quarry, this rate rose to 65–80% using the armed-chained cutting machine and block efficiency increased by 500–900%. The use of a domestic chained cutting machine will reduce waste and increase production efficiency, in addition to providing a safer working environment and simplified production processes. When the use of domestic armed-chained cutting machines becomes widespread in Turkey, the limited natural stone reserves will be utilized in a more efficient and economic manner.

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