O 52. NATURAL STONE CUTTING PLANTS AND AMOUNT OF WASTE PRODUCED

Ahmet Yıldırım[1], Mehmet Kemal Gökay[2]

[1]*Mining Engineer, Elazıg, Turkey, Turkey*
[2]*Konya Technical University, Mining Eng. Dept. Konya, Turkey*

E-mail: ahmet023yildirim@gmail.com, mkgokay@ktun.edu.tr

ABSTRACT: Marbles, travertines and andesite rocks have been common natural stones types economically mined in Turkey. When the waste, (unusable stone fragments, leftovers, micronized rock dust, slurry etc.) in consideration; wastes can be occurred in natural stone mines and additionally they can be produced in Natural Stone Dimensioning (NSD) plants. Wastes generated at a NSD plant near Elazig city (Turkey) have been perceived here to evaluate waste occurrence cases. When two typical equal sized natural stone blocks from the same stone mines are started to be dimensioned in a NSD plant (by using the same cutting and dimensioning machines), total saleable natural stone plates' surface areas (for the similar plates) obtained at the end of the operation might be different. It was aimed in this study to observe and understand governing (influencing) parameters of these differences. Actually, factors influencing waste amounts in NSD plants can be related with: cutting machine and its disk & blade performances; different plate dimensions (thickness, length, width); discontinuity contents; irregularities in natural stone blocks, problems related with block and plate handlings, mechanical property differences in stones blocks, natural stone dimensioning machine types and their properties etc. Detail evaluations of these parameters have been performed and amount of waste volumes and percentages were calculated here to compare main influencing parameters.

Keywords: Natural stone, Marble, Natural stone cutting, Waste in Natural stone cutting.

1. INTRODUCTION

Waste amounts related with Natural Stone Dimensioning (NSD) plants can be reached considerably high levels in certain mining regions. Afyon city in Turkey for example has special waste disposal area for NSD plants located near this city limits (Celik&Tur, 2012). Natural stones excavated from nature for their aesthetic appearances and some other physical and strength related properties. Marbles, travertine, andesite and granite rocks are famous natural stones in Turkey and there are always customers for them mainly from construction industry. In civil buildings, floor and wall covering layers, material, have been differentiated according to construction designs, aims. These covers can be different for museums, domestic houses & apartments, shopping centres etc. Natural stone plates prepared for surface covers are then good alternatives to catch customer's attentions during liquefactions of these assets in construction markets.

Natural stone mines have mostly operated by open pit operations. One of the main differences of natural stone pits from other open pit mines is the product of the natural stone pit. Mining operations in this case are arranged to handle, cut out, dimensioned rock blocks from the main rock masses. Therefore blasting operations and any other excavation methods which create abnormal vibrations are discarded. Natural rock masses have been cut into big in-situ blocks at benches by using powerful wire-cutters. These blocks are usually very big in dimensions (around 2x7x7 m). After smooth detaching operations, in-situ blocks have been cut into smaller block sizes (around 1.7x1.8x3.0 m) by bench-top wire-cutters. These small size blocks are then moved to mine stock sides for sales. Wastes occur during these mining operations are inevitable. Waste volumes in natural stone mining conditions are considerably high due to rock mass discontinuities. Yavuz (2001) worked on discontinuities in natural stone pits and their influence on block production. Ersoy etal., (2012) compared plate production efficiencies of small sized natural stone blocks (rubbles, broken leftover small blocks) with respect to normal sized natural stone blocks. These and similar works performed before had focussed on the wastes occurred in natural stone mines. In natural stone business, natural stone blocks can be cut into laminated plates to increase companies' market places and profits. Therefore, natural stone miners have also NSD plants. This study therefore concentrated mainly on stone wastes occurred at these NSD plants. It was aimed in this study

to understand what could be the percentage of total waste volume occurred during cutting of a natural stone block. It was also aimed to analyze factors influencing the resultant wastes.

2. MATERIALS AND METHODS

Waste produced due to NSD plant operations have been analysed during this study. It was aimed to observe natural stone cutting operations step by step to determine the main reasons of waste occurrences. Figure 1 presents main steps in NSD plants to obtain natural stone plates for sale. Natural stone blocks obtained from natural stone pits are first cut into big-scale plates by gang-saw machines. Then these big-plates are cut into dimensioned small plates (s-plates), which look likes rectangular, laminated, prism, (plates with 2-3 cm thickness). After that; s-plates' faulty parts are cut out to obtain saleable products. Final dimensioned stone products are then presented at company showrooms or internet web pages for related markets.

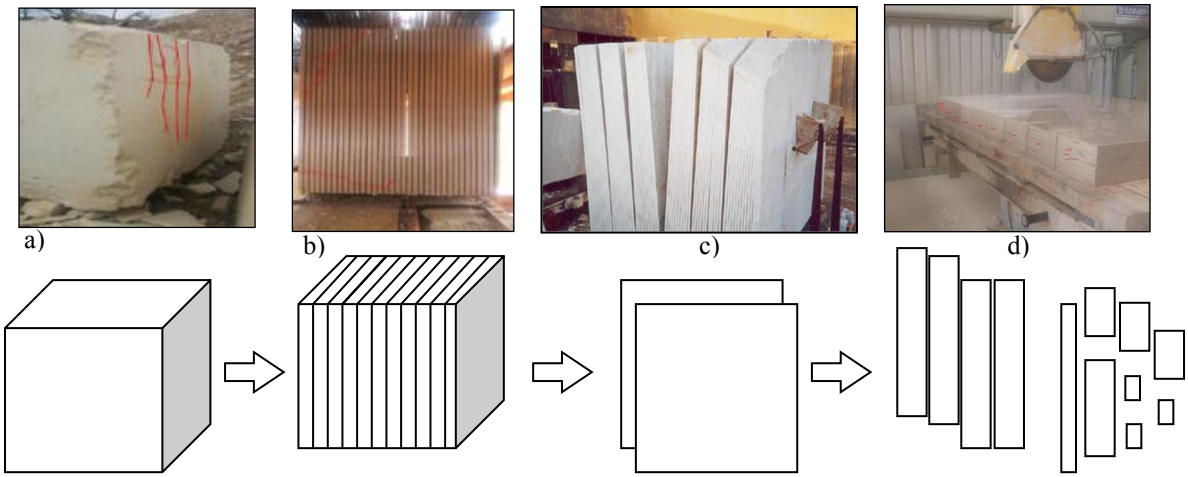

Figure 1. Natural stone block cutting steps to obtain dimensioned small plates

Like timber logging machines, natural stone cutting machines have special cutting saws. Unlike timber logging machine saws, natural stone cutters have extra hard and abrasive sockets (segments) attached to disk shaped saws or steel-rod shaped blade saws. In general, these segments put extra 0.3-0.8 cm thickness to saws's main metal (load carrying) structures. These segments cut stones by chipping actions by facilitating especially designed cutting machines. In order to continue the cutting actions, the segments cut out enough apertures in the stone (Fig.1b) which saw disks or blades move freely in. Natural stone cutting machines and their spare parts are produced by particular machine manufacturing industry which several companies in the world have competed. They have tried to produce more efficient and safer cutting machine models in each year. Therefore, NSD engineers can find (or they can order to manufacture) different saws for their natural stone cutting operations. These machines can be different in models and they might be equipped with different cutting disks or blades (with different cutting thickness). Assume that 2x2x2 m block is planned to divide into 2 cm thick big-plates like in Figure 1. In theory, this block has 100 big-plates capacity which have 2 cm thickness and 2x2m surface dimensions. In reality, natural stone cutting machines have blades which have 0.3-0.8cm thicknesses to cut the blocks. Therefore gang saw blade thicknesses (blade steel rod+segment thicknesses) should also be considered. This thickness was 0.5cm for Elazig-cream marble cutting and 0.4cm for onix cutting operations. In order to obtain 2cm thick Elazig-cream big-plates, 0.5cm aperture should be cut out among the plates by gang saw blades. This is the cause of waste occurred at gang saw machine operation and it is inevitable with this type of cutting technology. Then, for the given block example above; (200cm/2.5cm) = 80 big-plates can actually be obtained instated of theoretical 100 big-plates. Actual obtained big-plate numbers are then different for 0.4cm blade thickness (blade steel rod+segment thickness) as well. For this case; (200cm/2.4cm) = 83.33 big-plates can be obtained (*in this case; 83 big-plates can be obtained with 2cm thickness and in addition 1 more big-plate can also be obtained but its thickness is less than 1cm*). This operation cause lost of natural stone mass inevitably. Waste percentage calculated through numbers of big-plates (for the example assumed above) are;

i) Theoretical division without producing any slot aperture for blades= 100 imaginary big-plates
ii) Case 1: Actual 0.5cm slot aperture (for blades+cutting sockets)=80 big-plates (%20 lost)
iii) Case 2: Actual 0.4cm slot aperture (for blades+cutting sockets)=83.33 big-plates (%16.67 lost)

In this work of study, waste produced during dimensioned natural stone plate cuttings operations are researched through actual plant cases in Elazig city in Turkey. It is required to be point that, cutting the natural stone plates into smaller sized, s-plates, produces more wastes due to further cutting operations. To present this fact, one NSD plant cutting Elazig-cream blocks and another NSD plant cutting onix blocks were observed for their s-plate and big-plate productions respectively. In Turkey, s-plates cut from natural stones (usually; marble, travertine, andesite and granite) have 2cm in thickness. The other dimensions of these s-plates are listed below according to their usages (categories) described;

i) Plates for staircases, ladders; (2x30x60) cm,
ii) Plates for window sills; (2x14.5x free length) cm,
iii) Plates for (rooms, saloons, corridors etc.) floor cover; (2x40x40) cm,
iv) Plates for (rooms, saloons, corridors etc.) floor cover; (2x60x60) cm.

Observation method was used in this study. Waste and saleable products were closely observed for selected rock blocks. Due to natural characteristics, natural blocks transported to NSD plants had not similar in dimensions and discontinuity properties. Therefore, Elazig-cream and onix blocks were randomly selected at NSD plants' stock areas for their cutting procedures. Waste volumes produced during s-plate and big-plate cutting operations were then analysed step by step to evaluate the causes of the natural stone wastes in NSD plants. There are common acceptations on the basis of experiences about NSD plant wastes. This study on the other hand supplied actual NSD plants' data observed. Therefore it is more valuable (contains no bias) to evaluate natural stone block cutting operations and their wastes.

3. FACTORS INFLUENCING WASTE VOLUME IN NSD-PLANTS

When natural stone blocks are supplied to NSD plants, they are stocked at open areas which have suitable crane facilities for block handling. These blocks have gradually cut into big-plates or s-plates in NSD plants according to customer requirements. After analysing the cutting procedures in several NSD plants and observing closely the actual operations, it can be concluded that following factors are the main reasons of wastes in these cutting operations;

i) Slurry wastes due to saw machines;
It is slurry, muddy form of natural stone material. Saw machines cut the natural stone by opening aperture for their disks or blades. Thickness of cutting segments attached to disks and blades control the width of the apertures. These apertures are 0.4cm and 0.5cm for the observed NSD plants in this study. Natural stone materials in these apertures have been chipped away to separate stone plates. These chipping or powdering actions of saws create stone-slurry due to applied water spraying (dust control sprays).
ii) Wastes due to handling operations,
Organising works and duties in NSD plants require concentrated efforts. Sometimes workers have not careful enough to arrange natural blocks alignments in gang-saw machines. These faulty set-ups may cause extra leftovers, wastes. In addition, handling the stone plates in NSD plants needs full attentions. Plates fell from even small elevations cause extra breakages which increase the leftovers, wastes.
iii) Waste due to plate dimensioning;
Block cutting operation at gang saw machines produce big-plates. Due to unevenness of blocks' sides there are always small amount of leftovers at the left and right side of the natural stone blocks during gang saw cutting operations. Additionally, natural stone usage in construction industry is basically for aesthetic purposes. Therefore customers might require s-plates in different dimensions. When NSD plants have big-plates from blocks, next step is dividing big-plates to obtain s-plates. This cutting operation on big-plates creates leftovers (wastes) according to supplied s-plate sizes.

iv) Waste due to discontinuities;

Natural rock masses have discontinuities. Normal distribution peak value for rock masses presented that one can observe 1 joint every 1.5m of rock mass extensions. Natural stone reserves have discontinuities similarly. Some of these fractures are tightly cemented by natural rock minerals, so they will not create problems in cutting operations at NSD plants. But some of them cause extra breakages during cutting operations. When the number of cutting operations for the required s-plates is increased, waste due to breakages might be increased as well. Companies operated NSD plants have sometimes used epoxy polymers to cement fractures in natural stone blocks. These increase cost of big-plates and s-plates produced at NSD plants, but decrease dramatically waste amounts caused by discontinuities. NSD plants cutting onixes or similar valuable natural stones have preferred to apply different chemicals to decrease their waste originated due to discontinuities. Oztekin (2007) studied on epoxy-polyester chemical application on fractured marble blocks to present the effects of the applications and advantages supplied through.

v) Waste due to polishing;

After obtaining big-plates or s-plates, one face of each plate are selected for polishing operation. Originally, surfaces of these plates have traces of saws and blades's cutting segments. These marks or traces are firstly levelled by abrasives and then polished by brushes. These actions cause thinning of the plates. Stone slurry created in these operations are considered as waste.

vi) Waste due to sale conformity;

This is not the wastes occurred in NSD plants. It is related with marketing steps of big-plates of natural stones. It is an assumption. It is a stone volume, assumed as a "waste" volume due to marketing agreements between NSD plants and their customers. Big-plate customers in natural stone sector assume that; big-plates they are going to buy might have micro fractures at their outer skirts (other sides & edges) due to handling operations. Therefore, they would like to decrease actual surface areas of big-plates (a few centimetres from actual dimensions) to pay. It is assumed in this type of agreements that; outer skirts of big-plates are cut out to obtain actual payable, usable, plate areas. Thus, this waste is hypothetical and it does not increase waste volumes in NSD plant waste areas.

These factors are the main ones which create opportunity to waste natural stone block materials. It is important to mention that, natural blocks arrived to NSD plants are valuable assets when the whole mining procedures are considered. The costs of these blocks are high enough, so maximum natural saleable plates should be produced by controlled cutting operations. Table 1 and 2 present waste volumes and percentages occurred due to the factors described above. These values were obtained through NSD plants by close observations.

Table 1. Waste volumes turned out during natural stone cutting operations for s-plates and their percentages with respect to initial block volume

Block	Block volume, m^3	Slurry waste m^3, (%)	Waste due to handling m^3, (%)	Waste due to dimensioning m^3, (%)	Waste due to discontinuities, m^3, (%)	Waste due to polishing m^3, (%)	Total waste volume, m^3, (%)
Elazig cream-n1	1.5136	0.3027 (% 20.00)	0.0704 (% 5.81)	0.0496 (% 4.36)	0.1144 (% 10.48)	0.0521 (% 5.30)	0.5892 (% 38.92)
Elazig cream-n2	5.4600	1.0920 (% 20.00)	0.1040 (% 2.38)	0.2713 (% 6.46)	0.8248 (% 20.66)	0.1759 (% 5.59)	2.4682 (% 45.20)

Table 2. Waste volumes turned out during natural stone cutting operations for big-plates and their percentages with respect to initial block volume

Block	Block volume, m^3	Slury waste m^3, (%)	Waste due to gang-saw dimensioning m^3, (%)	Waste due to sale conformity m^3, (%)	Waste due to polishing m^3, (%)	Total waste volume, m^3, (%)
Onix-n1	1.9260	0.3211 (% 16.67)	0.0430 (% 2,67)	0.0718 (% 4.74)	0.0468 (% 3.00)	0.4825 (% 25.01)
Onix-n2	6.9552	1.1594 (% 16.67)	0.1370 (% 2.37)	0.1901 (% 3.44)	0.1368 (% 2.42)	1.6236 (% 23,34)

4. CONCLUSIONS

Natural stone plates have different aesthetic beauty therefore customers' preferences are important factors on their marketing conditions. Discontinuities and weakness zones in natural stone reserves are main decision parameters on their mining conditions. Modified open pit mining methods are applied in Turkey to cut and handle big stone blocks from their rock masses. There are waste and leftovers in natural stone mining conditions. However, this study have concentrated on waste occurred at NSD plants. After selection, natural stone blocks were transported to NSD plants, and waste occurred in these plants were researched to understand the levels according to cutting operations realized in the plants. Natural stones can be found in stone markets in 3 different categories, these are, block, big-plate and s-plate categories. According to natural stone types and companies' preferences, natural stones are supplied to market to maximise related companies' profits. Total waste volume occurred during cutting operations of these 3 types of saleable natural stone items are different also. In general, when stone blocks are cut into further small plate sizes, waste amounts are also increased. Waste volume occurred in NSD plants producing big-plates of onixes and s-plates of Elazig cream marbles were observed to evaluate the scale of wastes. Total waste percentages for big onix plates production and Elazig cream marble s-plates production were obtained approximately % 25 and % 41 respectively. Observation presented that epoxy polymers coverage of stone blocks have almost eliminated waste occurred due to discontinuities. It is also important to point that, main part of total waste amounts is produced in cutting operations at gang saw machines. Cutting blade-segment thickness is main influencing factor on these machines' waste production. These thicknesses were 0.5cm and 0.4cm in this study and the resultant waste percentages were around % 20 and % 16.67 respectively. Consequently, cutting technologies applied in NSD plants' cutting machines *(covering: thinner blade-disk cutting segment usage; decreasing machine vibrations; stable plate holding apparatuses; robotic arms for plate transfer between cutting machines etc.)* are one of the main influencing factors in NSD plant waste production. Another factor is stones' discontinuity content. Some part of waste occurred due to handling at NSD plants can also be related with discontinuities. Thus, fractures can cause extra breakages during s-plate handling among cutting machines. Experiences have demonstrated that; epoxy polymer applications on fractured natural stone blocks have generally stabilized the discontinuities before cutting operations. Therefore, epoxy polymer applications can be accepted as governing influencing factor on NSD plants' waste volumes.

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