# MANAGEMENT OF CONSTRUCTION MATERIALS CRUSHING ACTIVITIES

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## ABSTRACT

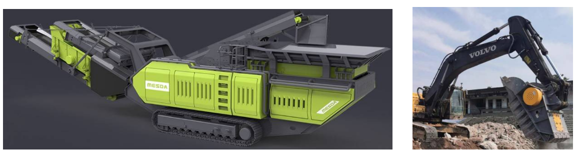
*In this paper, the author presents aspects often encountered on construction sites related to management and organization activities when mobile crushers with hammers are used. Cases of good practice are detailed (with aspects of maintenance and selection of appropriate work technology) so that the work is executed on the required deadline, with increased efficiency, and the life span of the technological equipment is maximized. Also, the theme of the work is of interest to specialists in the field of site organization and management.*

KEYWORDS: management, crusher, hammer, life span, efficiency

## 1. INTRODUCTION

The crusher is a machine used in construction to reduce large rocks into smaller pieces, gravel, sand or rock dust. In large part, the exploitation of the crushing results consists in obtaining the raw material in the form of mineral aggregates for the preparation of concrete recipes or asphalt mixture. Therefore, the crushers are used to reduce the particle size to such an extent that the material can be processed into finer particles more easily with the help of other specialized technological equipment. In operation, the raw material (of various sizes) is usually delivered to the hopper of the primary crusher with the help of tippers, excavators or front loaders.

From a constructive point of view, these technological equipments are available in two versions: fixed and mobile. As a result of the versatility of the construction equipment, crusher buckets of different capacities can be mounted on the excavators (fig. 1).



(a) (b)

Fig.1. Constructive equipment for crushers [1,2]:
(a) mobile; (b) bucket crusher on excavator

An overview of the industrial use of crushing shows that the most common are in mining activities and in quarries where crushers are used classified according to the degree of fragmentation of the raw material.

## 2. CASE STUDY ON REPLACEMENT OF INSTANT FAILURE COMPONENTS IN A CRUSHER

On construction sites, the management of activities that involve the use of crushers includes aspects regarding the timely change of working bodies subject to wear (fig. 2), as well as the establishment of the most appropriate technological solution for the execution of works with high efficiency. Some general considerations about these aspects will be detailed below.

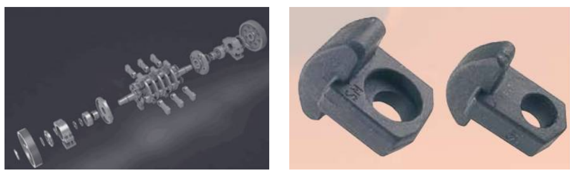


Fig.2. View over working bodies (hammers)

For example, as part of an activity involving the processing of aggregates, 6 pieces of equipment such as hammer crushers are used in the technological flow, arranged in stationary ballast. They provided the working components in the form of impact elements that have the property of being interchangeable when their failures occur caused by excessive wear or overloads during the work process (which leads to their cracking or breaking).

The hammer has a life span that is limited, and regarding this aspect the following data are available regarding failures occurring over time, as follows:

- the number of weeks since the last replacement, ni = 4;
- percentage of components (cumulative) that failed at the end of each week:

n1 = 25; n2 = 55; n3 = 85; n4 = 100.

It is also known that the 6 crushers work with several 100 working hammers. They can be replaced en masse at a cost of €3 for each component replaced. If the hammers are replaced individually, as soon as one has failed, then the cost is €15 for each component replaced, meaning €1.50 for the component and the remaining €13.50 for the labor cost.

In this case study, the objective is to establish the most effective replacement strategy for the company that owns this technological crushing equipment, by comparing the two situations: the individual replacement of the hammers as they fail with the possibility of their total replacement, at the end of a certain number of weeks of operation, at the same time as replacing the components that have failed during this time.

Starting from the fact that the weekly proportion of failures is known:

n1 = 25; n2 = 30; n3 = 30; n4 = 15; ∑ni = 100%,

gives the average life of each hammer:

1x0.25+2x0.30+3x0.30+4x0.15=2.35 weeks.

The average number of replacements performed weekly is as follows:

180 / 2.35 = 77.

The cost of individual replacement according to the failure of the hammers is calculated with the relationship:

77 weeks x €15 = €1155/week.

To be able to calculate the costs involved in the mass replacement of the respective hammers, it is necessary to determine in advance the number of failures that can occur per week, considering the percentage of original hammers that fail, including already replaced hammers that fail requiring a new replacement.

For a centralization of all information related to this case study, table 1 will be filled with the number of individual failures resulting from the summation of the number of failures occurring in the batch of 180 defective interchangeable hammers that were replaced.

Table 1 Failures of the interchangeable hammers of a crusher

| | Week 1 | Week 2 | Week 3 | Week 4 |
|---|---|---|---|---|
| 180 pieces (originals) | 36 | 54 | 54 | 36 |
| 36 pieces (replaced in week 1) | | 7 | 11 | 11 |
| 54 pieces (replaced in week 2) | | | 11 | 16 |
| 54 pieces (replaced in week 3) | | | | 11 |
| 7 pieces (replaced in week 2) | | | 1 | 2 |
| 22 pieces, 11+11, (replace in the week 3) | | | | 4 |
| Total failures | 36 | 61 | 77 | 80 |

The total cost results from the cost of mass replacements plus the cost of individual hammer replacements. Thus, it follows:

a) week 1:
- total cost, CT=36x15 € +1500 €=2040 €;
- average weekly cost, CMS = € 1155;

b) week 2:
- total cost, CT=97x€15 + €1500=€2955;
- average weekly cost, CMS = €1078;

c) week 3:
- total cost, CT=174x€15 + €1500=€4110;
- average weekly cost, CMS = €1370;

d) week 4:
- total cost, CT=254x€15 + €1500=€5310;
- average weekly cost, CMS = €1327.

Comparatively analyzing the results, it can be observed that the best strategy that the company owning technological crushing equipment can adopt is to completely replace the hammers, during the second week of operation.

## 3. COMPARATIVE STUDY BETWEEN THE EFFICIENCY OF USING A CRUSHING BUCKET AND MOBILE CRUSHER AT A QUARRY ACTIVITIES

Establishing the optimal exploitation of specialized technological equipment for processing mineral aggregates from a quarry, for example, requires careful planning, taking into account the volume of materials to be processed so that the total costs do not affect the decrease in profit. In this sense, the best option is sought, with the technological resources and the most suitable technologies so that the execution of the work is carried out with a minimum cost, during the imposed period and at a specified quality level.

A technology that has begun to be applied consists in the introduction of crushing buckets mounted on loaders or excavators into the work front, in this way crushing the aggregates by moving the basic machine to the place where the respective activity must be conducted. Both primary and secondary crushing can be done with crushing buckets.

In the case of applying the classic crushing technology, fixed or mobile crushing stations are used, which require the performance of several work phases, such as: transporting the material near the crusher, and then with the help of a front loader it is introduced into the mobile crusher. The presence of these construction machines involves multiple activities [3], which create in the technological flow the dependence of one machine on the others (that is, they cannot work if one is missing or breaks down). In this case, the capital costs are high in the beginning, and the need for specialized personnel to work on these machines is increased.

By making the decision to integrate the bucket crusher in the processing activities of mineral aggregates or materials resulting from the demolition of buildings or road repair [4], several advantages should be emphasized, such as: lower initial investment of capital costs, no need for a crusher specialized mobile and the need for operating personnel to service the classic mobile crusher. With the use of the crusher bucket, it will be present everywhere the excavator/loader will travel, which means that it will run in all terrain conditions, even in small spaces.

Although the proposed method is theoretically correct, it can be difficult to apply in a direct manner in the conditions of a mining site. Crusher bucket productivity can also be determined by measuring the duration of each operation in an excavator's work cycle.

The working cycle time of the crusher bucket excavator can be determined with the following relationship:

$$T_C = t_1 + t_2 + t_3 + t_4 \text{ [min.]} \qquad (1)$$

where: $T_C$ is the duration of the work cycle, in min; $t_1$ – digging time, in min; $t_2$ – the time to perform the rotating and lifting maneuvers of the cup, in min; $t_3$ – material crushing time, in min; $t_4$ – time to perform the cup unloading maneuver, in min.

The number of cycles of loading the bucket and crushing the material in the bucket, during one hour, can be calculated with the following relationship:

$$N = 60 / T_C. \qquad (2)$$

Depending on this parameter, the hourly productivity of the crushing bucket is determined as follows:

$$Q_h = qNk_u / k_a \text{ , (m}^3\text{/h)} \qquad (3)$$

where: $q$ represents the capacity of the cup, in m$^3$; $k_u$ - coefficient that takes into account the degree of loading of the cup with material; $k_a$ - coefficient of loosening of the material loaded in the cup.

Work productivity with crusher bucket during a work shift is calculated with the formula:

$$Q_{work\ shift} = Q_h T_s k_1 k_2 k_3, \text{ (m}^3\text{/work)} \qquad (4)$$

where: $T_s$ is the duration of the work shift, in hours; $k_1$ – coefficient that takes into account the technical efficiency of the excavator; $k_2$ – coefficient that takes into account the waiting time of the dump truck or dumper that will pick up the crushed material, during a work shift; $k_3$ – coefficient that takes into account the time in which the machine did not work, during a work shift.

The annual productivity of work with crusher bucket results:

$$Q_{year} = Q_{work\ shift} N_s, \text{ (m}^3\text{/year)} \qquad (5)$$

where $N_s$ is the number of exchanges in a year.

In most cases, quarry operations involve the use of an excavator, a front-end loader, a dump truck or dump truck, and a mobile crusher. The productivity of crushers working varies between 200 t/h to 400 t/h and can crush aggregates up to 600 mm in size.

For example, big crusher bucket models are available for excavators with an operating mass in the range of 70...100 tons, with the dimensions of the unloading area 1450 x 700 mm, with the possibility of adjustment by 100 to 200 mm. This technological equipment is particularly efficient for the primary crushing of mineral aggregates or other types of materials, being recommended for the execution of these activities on a large scale.

The small crusher bucket models are available for excavators with an operating mass between 30...45 tons and have a bucket with unloading dimensions of 1205 x 540 mm. The size of the aggregates that can be processed is from 15 to 145 mm, and these buckets are recommended for use in secondary crushing.

Both bucket models are indicated for use in loading and processing mineral aggregates, including very hard rocks. From the information available on the websites of manufacturers of such kind of buckets, the average duration of a complete work cycle consisting of loading, crushing, unloading takes about 2 minutes.

Thus, three work cases will be described:

a) calculation for the use of a single excavator with a crushing bucket with a capacity of 2.2 m$^3$:

$N_C$=60/2=30 cycles per hour;
$Q_h$=2.2x30x0.65/1.4=30.6 m$^3$/h;
$Q_{work\ shift}$=30.6x8x0.9x0.95x0.95=
=198.8 m$^3$/work;
$Q_{year}$=198.8x240=47713 m$^3$/year.

b) calculation for the use of a single excavator with a crushing bucket with a capacity of 1.35 m$^3$:

$N_C$=60/2.2=27 cycles per hour;
$Q_h$=1.35x27x0.8/1.3=22.4 m$^3$/h;
$Q_{work\ shift}$=22.4x8x0.9x0.95x0.95=145.5 m$^3$/work;
$Q_{year}$ = 145.5x240 = 34920 m$^3$/year;

c) calculation for the use of a single excavator with a standard bucket with a capacity of 1.7 m3 and productivity during a work shift of 8 hours:

$N^C$=60/0.35=171,4 cycles per hour;
$Q_h$=1.7x171.4x0.8/1.3=179.3 m$^3$/h;
$Q_{work\ shift}$=179.3x8x0.8x0.95x0.95=
=1035.6m$^3$/work;
$Q_{year}$ = 1035.6x240 = 348544 m$^3$/year.

The scheduling of activities for the performance of crushing works can be done considering two technological variants, illustrated in Table 2.

The green color represents the two crushing buckets, and the blue color symbolizes the standard bucket of an excavator that feeds a specialized mobile crusher.

Based on the results obtained in conjunction with the objective functions and the constraints of the work to be executed, the site manager will make the correct decision.

Table 2. Presentation of two technological variants

| | Work shift 1 (hours) | | | | | | | | Work shift 2 (hours) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Excavator 1 (Crusher bucket, q=2,2m$^3$) | | | | | | | | | | | | | | | | |
| Excavator 2 (Crusher bucket, q=1,35m$^3$) | | | | | | | | | | | | | | | | |
| Excavator 3 (Normal bucket, q=1,7m$^3$) | | | | | | | | | | | | | | | | |

## 4. CONCLUSIONS

Among the various types of crushers used in the construction material crushing industry, only those with hammers were addressed in this work, by presenting some case studies regarding the management of these activities on construction sites. The main objective sought to be achieved was to increase the efficiency of the works conducted.

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