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Research Paper

Energy Management in Cement Plant Mills with Optimize Plan for Extraction and Blending of Mining Zones

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Abstract: Considering the consumption of more than 25% of energy by raw mill materials in cement plants, providing a suitable plan for blending different mining zones can be an effective approach in reducing the energy consumption. The purpose of this paper is optimizing the plan of blending limestone mining zones to reduce milling energy consumption raw mills (ball mill and HPGR). The geomechanical properties of different mine zones have been identified by performing the bond work index, drop weight, and uniaxial compressive strength (UCS) tests. Also, to comply with cement production standards, cementing modules including S.I.M, A.L.M, and L.S.F have been calculated for different mine zones. Mining production planning with the aim of achieving the minimum comminution energy and transportation costs has been developed by the Goal programming method. Planning constraint equations are also considered to regulate cement modules. Finally, utilizing windows Quantitative System for Business software, the necessary calculations have been carried out. Based on the results, the extraction order and blending values of different mine zones are adjusted regarding cement modules and minimizing transportation costs, leading to a reduction in energy consumption of raw mills.

Keywords: Cement, Raw mills materials, Comminution tests, Cement modules, Goal programming.

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INTRODUCTION

After chemical, petrochemical, and metal industries, Non-metallic industries (Non-metallic mineral products comprise of cement, ceramics, glass, and lime) with about 12% of global energy consumption. is the third-largest consumer of energy in the world [1]. Cement factories as sub-industries of non-metallic industries, consume about 2% of the total global energy and 5% of the total industrial energy [2-4]. The average consumption of electricity and fossil fuels in a cement plant is 119 kWh/ton and 105 lit/ton, respectively. Despite the high energy consumption, the cement industry is considered a low-yield industry with an efficiency of 60 to 70% [5]. The low efficiency of cement plants is directly related to the inefficiency of their comminution circuits; because more than 60% of energy consumption is related to crushing and grinding units, especially raw materials and clinker mills [6,7]. Low efficiency of milling circuits leads to increased production costs; conversely, a slight increase in the efficiency of milling circuits can significantly reduce production costs. The selection of raw materials, which have the necessary characteristics to produce the desired cement and, on the other hand, have low comminution indices (bond work index, drop weight, and axial strength), will reduce energy consumption in the milling section and thus in the entire cement plant [6].

The purpose of this study is to optimizae the blending of limestone mine zones for comminution energy reduction in the raw mills of cement plant. The raw materials (mined) are transferred to the mills for pulverization based on the mineral composition determined in the X-ray laboratory (to adjust the modules). Energy consumption in these mills is largely dependent on the comminution properties of raw materials and the raw material blending ratio. Therefore, the blending plan regarding the geomechanical properties and the grindability of different zones (zones) of the mine, especially the limestone mine which supplies about 75% of the raw material for cement production, will have a significant effect on the reduction of energy consumption in the comminution of raw materials. For this purpose, the geomechanical properties and grindability of different zones of the mine have been investigated. To determine the required comminution energy of each face's rock in mills, the relevant sample was subjected to comminution tests such as the drop weight test and the bond work index, as well as the uniaxial compressive strength test. Finally, using windows Quantitative System for Business (WinQsb) software, the objective equations were determined, and according to the tests to determine the grindability and constraints, including cement modules and transportation costs in the system, mathematical calculations to optimize energy consumption and production planning have been performed.

METHODS

Rashkan limestone and marl mine with a reserve of 200 million tons, belongs to Urmia cement company-owned. In this mine, Miocene limestone deposits are often in the form of thick layers, and in some cases massifs, which are inter-finger with marl deposits. The lower and upper layers of these limestones are not recognizable due to the lack of a specific layer. This issue is also due to the geological features of the Qom formation, in which the limestone and marl deposits of Rashkan are located. For a detailed study of the quantitative and qualitative characteristics of the mineral reserve, and taking into account the geomechanical characteristics as well as the technical characteristics, the limestone mine and depots stored at the factory site are divided into 10 zones (or faces), 7 zones for limestone in the mine area, and 3 other zones are divided into silica, iron ore and clay depots. Figure 1 shows the zoned areas in the aerial image. It should be noted that codes X1 to X7 are related to different zones of a limestone mine, X8 is clay depot, X9 is iron ore depot, and X10 is silica depot. The aforementioned zones are located at different distances from the factory' so, it is necessary to pay attention to the distance between the zones and the transportation costs.

FINDINGS AND ARGUMENT

As a general result, the different zones of Rashkan limestone mine can be classified in the following order according to the amount of energy consumption in the raw mill (ball mill of Urmia cement plant):

for Ball Mill Grinding: X1 > X3 > X4 > X6 > X5 > X2 > X7

Accordingly, zone 1 will have the highest energy consumption and zone 7 will have the lowest energy consumption per unit weight ground in the mill. However, this classification can be altered due to the lack of some data and the proximity of available data. Considering the values of the bond work index and

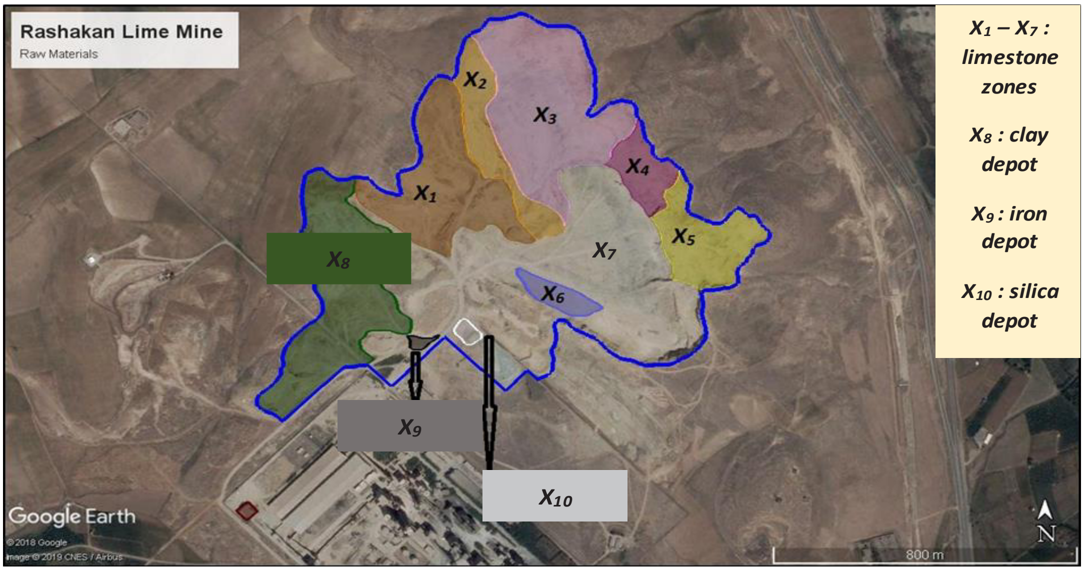

Figure 1. Aerial image of zoning in the area of Rashkan limestone mine in Urmia and cement-related raw material depots using Google Earth Pro software

Table 1. The amount of energy savings of each region compared to the hardest region

Zone	Maximum value	The amount of energy savings of each region compared to the hardest region (%)						
		X1	X2	X3	X4	X5	X6	X7
Wi (kWh/t)	13.0	0.0	-20.8	0.0	-20.0	-21.5	-16.9	-24.6
UCS (Mpa)	34.7	-8.9	-39.2	-27.4	0.0	-32.9	-42.9	-33.4

obtained A*b values, zone 1 undoubtedly has the highest energy consumption per unit weight in ball mills, and after that, is zone 3. The lowest energy consumption belongs to zone 7. Zones 2, 4, 5, and 6 have very close comminution properties and their energy consumption will not be much different. By applying more comminution parameters, the classification of these zones can be changed.

In the case of utilizing a HPGR, this classification of Rashkan limestone mining zones can be changed as follows:

for HPGR Grinding: X1 > X4 > X3 > X5 > X7 > X2 > X6

To determine the amount of energy (or power) efficiency or energy savings in different zones, it is necessary to know which parameters, such as grinding indices, texture and ore structure, type of failure mechanism, etc. are affecting it. However, in this study, it can be determined based on the type of mill and, as a result, the grinding index related to that mill can be applied. In the case of phase 1 of Urmia cement plant, which utilizes a ball mill, the bond index will be utilized as the main measurement tool for determining the reduction in power consumption per tonnage of feed entering the mill. For this purpose, the zone with the highest Wi is assumed as the base zone and the energy reduction percentages of other zones are obtained from the $\frac{W_{Xi} - W_{max}}{W_{max}} \times 100$ relation. According to the results, despite the Wi values of zones 1 and 3 being equal, zone 1 is the hard zone (maximum grinding energy); therefore, the energy reduction of other zones will be compared to this zone. In the case of phase 2 of the Urmia cement plant, which utilizes HPGR, uniaxial compressive strength will be the main criterion for determining the reduction in mill power consumption (energy). For this purpose, the zone with the highest UCS is assumed as the base zone and the energy reduction percentage of the other zones is obtained from the $\frac{UCS_{Xi} - UCS_{max}}{UCS_{max}} \times 100$ relation. According to the results, zone 4 is the hard zone (maximum failure resistance); therefore, the energy reduction of other zones will be compared to this zone. The results for both indices are given in Table 1.

In Table 1, a negative sign indicates the amount of energy reduction in terms of the percentage of different zones compared to the most resistant zone. The results of this table show that in the case of the ball mill, the highest energy reduction belongs to zones 7, 5, and 2, and in the case of HPGR, the highest energy reduction belongs to zones 6, 2, and 7.

Short-term production planning was limited to the formulation of equations, taking into account the simultaneous grindability and modules adjustment, as well as economic considerations (from the perspective of energy consumption reduction in raw mills and transportation costs reduction to crushing facility). Inserting these equations in the model of ideal programming and solving by simplex method, the order and the values extracted from each active mine zone were determined. In approaches A and B, the extraction tonnage was determined for the production of cement types 1 and 2 in plant phase 1, respectively. In approaches C and D, the tonnage extracted from the mine zones is determined for plant phase 2 and cement types 1 and 2, respectively. According to Table 2, currently, the most optimal composition and sequence for limestone mine exploitation is mining from zones No. 2, 6, and 7. The mine zone with the most extracted material tonnage is zone No.7, followed by zones No. 6 and 2, respectively. Due to the existence of seven active zones in the mine and also according to the operating conditions of the benching method from the existing open-pit limestone mine, it is necessary to re-prepare and re-arrange the short-term production planning, order, and sequence of optimal exploitation after extracting the mentioned zones up to the bench height. Also, due to the limitations in the regulation of cement modules and according to Table 2, it can be stated that in the present program, there will be no need to harvest the clay depot (X8); that is, the cement modules will be per standard by combining the materials extracted from zones No.2, 6, and 7, as well as the silica and iron depots based on the tonnages of Table 2.

Table 2. Optimal approaches obtained from solving the ideal planning model in Rashkan Cement Plant

No.	Decision variables	Phase 1		Phase 2	
		Optimal values A	Optimal values B	Optimal values C	Optimal values D
1	X1	0	0	0	0
2	X2	1151.22	802.69	1255.87	875.66
3	X3	0	0	0	0
4	X4	0	0	0	0
5	X5	0	0	0	0
6	X6	4544.72	4913.63	4957.88	5360.32
7	X7	9442.73	9182.12	10301.17	10016.86
8	X8	0	0	0	0
9	X9	348.37	442.16	380.04	482.35
10	X10	1012.95	1159.41	1105.04	1264.81

CONCLUSIONS

Raw mills are one of the major consumers of energy in cement plants, where energy consumption is directly related to the geomechanical properties of the input load and the operating parameters of the comminution circuit (including the type of the mill). Mining production planning according to the blending ratio of mining zones and other raw materials for cement production based on their grindability, can have a significant impact on comminution optimization in raw mills. In this study, by zoning the limestone mine (cement plant feed) based on geomechanical and tectonic characteristics and examining the grindability of each zone, the mine zones were classified according to energy consumption. The hardest zone has a bond index of about 13 kWh/ton and the lowest comminution energy is measured around 10 kWh/ton. Cement modules were calculated for each zone and their usage amount was calculated to determine the mixing ratio of the zones (to determine the desired quality of cement) and the amount of exploitation from silica, iron, and clay depots. Also, in production planning, the type of raw mill and comminution system was considered. Finally, the use of the ideal production planning to reduce grinding costs as well as transportation costs from the mine to the factory, considering the constraints of cement modules estimation, leads to determining the mixing ratio of materials from various mine zones and depots of raw materials (silica, iron, and clay). This production program will lead to the lowest comminution costs in raw mills.

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