ISSN 2229-5518

Determination of Bond Work Index of Lucky Cement Limestone Pakistan

Niaz Muhammad Shahani, Zhijun Wan, Abdullah Rasheed Qureshi, Muhammad Ali, Naseem Ali

Abstract—The Bond work index is a research methodology, which is widely used for the estimation of power required to grind the materials. Keeping in view the difficulty in determining this index, many alternatives to the standard method have been explored by the different researchers.

The study is focused on comminuting behavior of limestone and calculation of energy requirements for the effective production of ultra-fine particle up to mesh liberation at Lucky Cement Limited. In this regard calculation of work index of limestone made by standard Bond grindability test. Ball mill was employed to conduct the grinding test of seven different samples. Among all seven samples collected from the different faces of quarry, Bond work index of limestone Face-4A results less than 20kwh/t, remaining 6 samples are marked as hard rock because of high energy consumption and low grindability rate.

Index Terms— Ball mill, Bond Work Index, Comminution, Grindability, Liberation, Limestone, Ultra-fine particles

---

1 INTRODUCTION

IN a mineral processing plant, comminution is the process, to reduce the size of solids into small pieces in a mill [1]. The factors crushing and grinding are mostly considered expensive steps in mineral processing field as the comminution is source of large consumption electricity in mineral processing plant. The literature shows that the impact of energy as it consumes approximately 3-4% electricity throughout world and overall 70% energy is needed for mineral processing [2], [3], [4], and [5].

Over the years, there have been numerous experiments relating to grindability but two of experiments among them are considered to be most important and hence they are identify as basis for design and development of multiple type of mills. One of them is Bond Work Index having association with ball mill and second one is Hardgrove Index which shows strong association with Vertical Spindle Mill.

The best experiment is standard Bond Work Index (BWI), which associates the energy or intensity of energy required to minimize from initial size of mass of material up to and ultimate product size. The text considered as grindability is widely recognized and used for prediction of ball and rod mill energy which is necessary for selection of plant scale comminution equipment [6].

1.1 Brief Introduction of Lucky Cement

Det The lucky Cement Plant is located at main Hyderabad Karachi super-highway. It is scattered at large limestone deposits which are linked with village Jaman and Babar Bundh new district Jamshoro. The site of the plant is about 100km in front of roadside and the depth towards south is 2000km. The geology of lucky cement limestone is known as Gaj-formation and it belongs to Miocene age. In order to comprehend the required demand of production 10,000 tons per day, limestone is extracted by open-pit quarry method for the manufacturing of cement purpose.

• *Niaz Muhammad Shahani is currently pursuing Masters degree program in Mining Engineering in School of Mines, China University of Mining and Technology, China, PH-+8615162117508. E-mail: shahani.niaz@gmail.com*

TABLE 1
COMPOSITE THICNESS AND CaO AND SaO CONTENTS OF LUCKY CEMENT LIMESTONE

Limestone	Thickness (m)	Percentage (average)	
		CaO (%)	SiO_2
Face-2A	08	49.64	**5.40**
Face-4A	15	48.77	**4.58**
Face-4B	17	49.77	**4.80**
Face-5A	08	49.52	**5.06**
Face-5B	13	48.77	**5.19**
Face-6A	10	49.85	**5.78**
Face-6B	15	51.01	**6.07**

AVERAGE THICKNESS= 12m (approximately)

Fig. 1(a). View of Lucky cement Plant

Fig. 1(a). View of Lucky Cement Limestone quarry

1.2 Description of Ball Mill

The ball mil is the machine, which grind the solid materials into very fine powder and it is used for mineral processing, paints, ceramics etc.

The principle of ball mill is works on the impact, that during the operation size of material is reduced by impact when the balls falls from close the top of shell

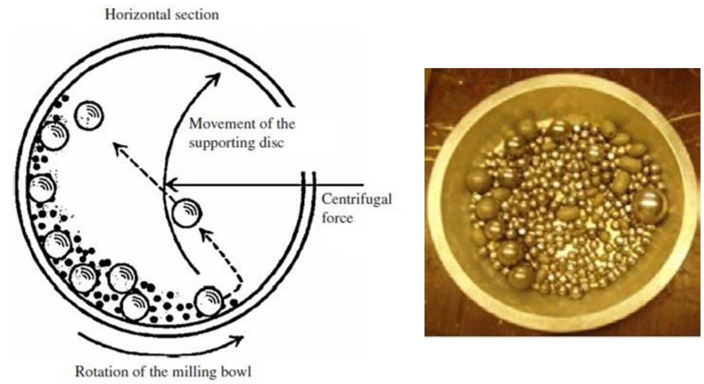


Fig. 2.

(a). Working principle in mill [7]

(b). Stainless steel balls for mill

2. Materials and Methods

2.1 Experimental Materials

Samples of limestone were collected from the Lucky Cement Ltd. This plant is situated at 58km of super highway from Karachi. The seven representative samples were prepared separately for Bond's Standard Method.

2.2 Bond Work Index

The term standard Bond grindability method/test is a closed-cycle dry grinding and screening process, which is taken into consideration until the steady conditions are obtained [8], [9] and [10].

For this purpose machinery is required Figure 2 which as Ball mill with diameter 152mm and length 305mm with rounded corners and a smooth internal lining. The total number of the ball charges are 285 which are given below;

The total number of ball charges and their diameter

No of Balls	Size (mm)
67	30
10	25
43	22.2
71	19.05
94	15

ISSN 2229-5518

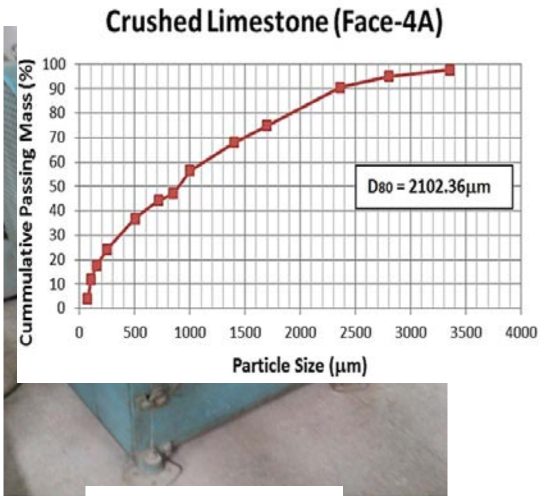


Fig. 3. Ball Mill

Talking about calculations, the speed of rotation is 70 rpm and sieves are also required. The material having weight of 700cc volume sample with the balls was charged into the ball mill. In the first cycle mill reaches 100 revolutions and stopped subsequently. The pulverized material is taken away from the ball mill is sieved on the selected test mesh screen (106µ). The undersized mass is separated and weighted, and oversized mass with a new quantity of 3350µm in order to obtain 700cc of material again charged into the mill.
Prior to starting of another cycle, it is required to specify the number of revolutions. The theoretical circulating load is carefully calculated as 250%. This clearly rejects the (oversized mass)/fines (undersized mass) and hence ratio is equal to 2.5. It also indicates that feed/fine proportion is equal to 3.5 and undersize mass shows 28.6 % of the fresh feed. After finishing the second cycle, process is repeated until the proper weight of undersized output per mill revolution access the constant value. To achieve the desire test result, 3-6 cycles are necessary. Consequently, the Gbp is calculated and considered to be ball mill grindability on the basis of average of net undersized mass per revolution taken from last three cycles.

$$\mathbf{G_{bp}} = g/rev \qquad (1)$$

Where g = mass of (106µm) undersize in gram
rev = number of revolution of the mill

The work index is then calculated as unde
Where,

$$W_i = \frac{44.5 \times 1.1}{{P_f}^{0.23} \times G_{bp}^{0.82} \times \left(\frac{10}{\sqrt{P_{80}}} \times \frac{10}{\sqrt{P_{80}}}\right)} \; in\, kWh/t \qquad (2)$$

P_f = test sieve product (106□m)
G_{bp} = G = the mill grindability in g/rev,
P_{80} = sieve with 80% of passing of the product and
F_{80} = sieve with 80% of passing of the feed.

The following table indicates some typical figures, and a relative measure of work index.

TABLE 2
USUAL VALUES OF BOND WORK INDEX

Bond Work Index	7-9	9-14	14-20	+20
Material Property	Soft	Medium	Medium-hard	Very hard

3 RESULTS

Limestone samples collected from Lucky Cement Limited are subjected to crush by means of Jaw crusher. After comminution, sieve analysis of standard sizes -3350µm (less than 3350µm in size) is conducted to for the bond grindability test. Results of the particle size distribution of crushed limestone of all seven samples were collected from the different faces of quarry are given as following

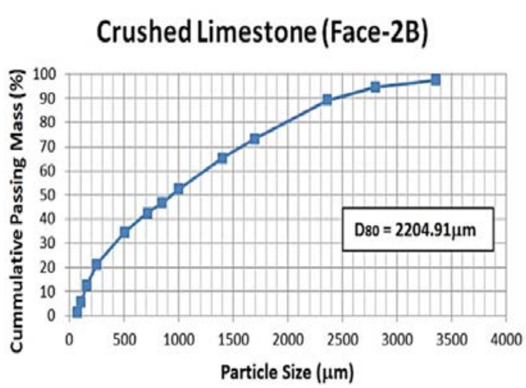


Fig. 4.
Commulative passing mass (%) with respect to particle size (µm) of crushed limestone Face-2B

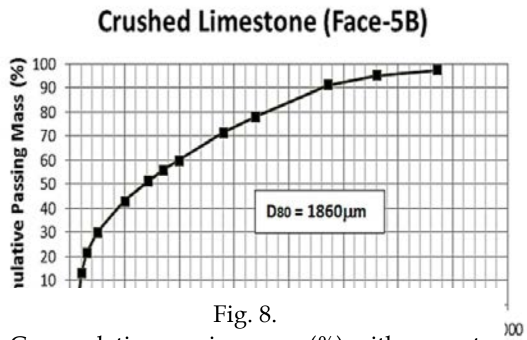


Fig. 8.
Commulative passing mass (%) with respect to particle size (μm) of crushed limestone

espect
tone

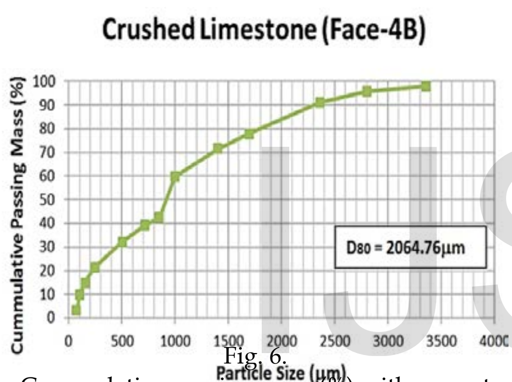


Fig. 6.
Commulative passing mass (%) with respect to particle size (μm) of crushed limestone Face-4B

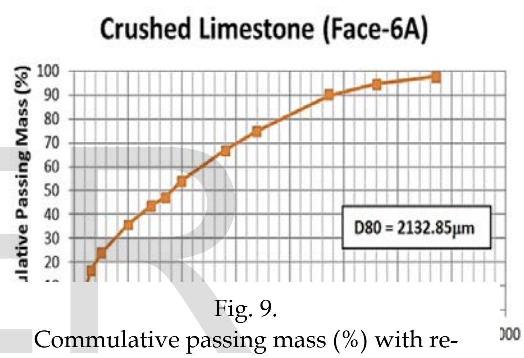


Fig. 9.
Commulative passing mass (%) with respect to particle size (μm) of crushed limestone Face-6A

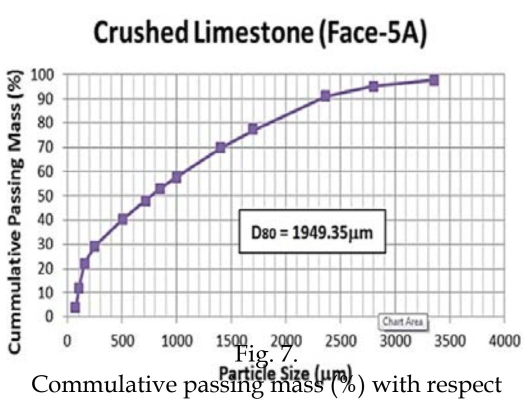


Fig. 7.
Commulative passing mass (%) with respect to particle size (μm) of crushed limestone Face-5A

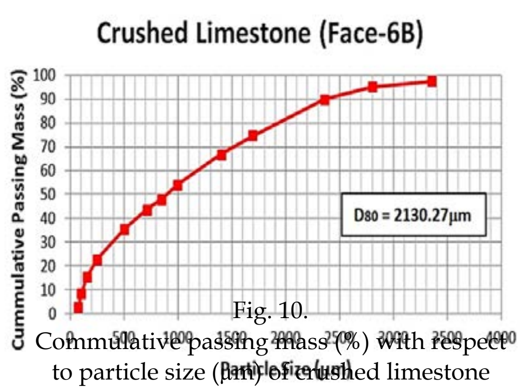


Fig. 10.
Commulative passing mass (%) with respect to particle size (μm) of crushed limestone Face-6B

After each grinding cycle in Fig. 11, the 80% product size (P_{80}) obtained from particle size analyzer.

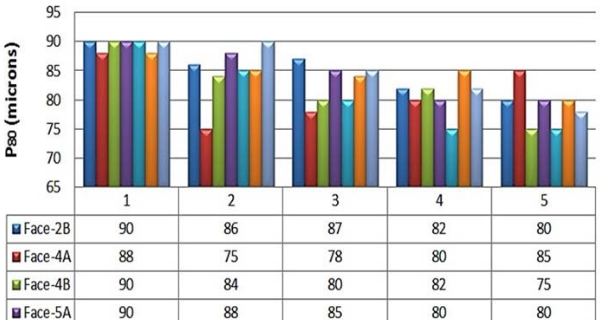


Fig. 11.
Product size (P_{80}) of each grinding cycles

Number of Cycles

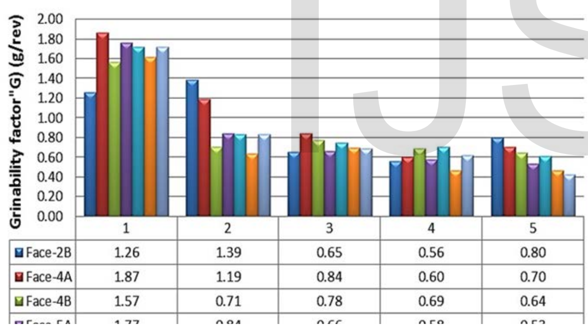


Fig. 12.
Grindability factor of each grinding cycles

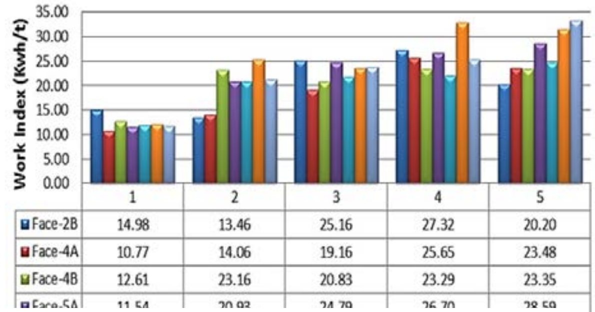


Fig. 13.
Values of Work index w.r.t number of grinding cycles

Number of cycles

Figures 12-13 indicates the grindability factor (G_{bp} or G) and work index (W_i) with respect to each grinding cycle.
According to the standard procedures, for the determination of the work index, -3350µm required samples were prepared. The standard Bond grindability test is a closed cycle dry grinding and screening process and it is carried out until the favorable results are obtained.

Table 3 shows the results obtained by using Bond's test, the average work index of all samples are more than 20kwh/t except Face-4A.Which means that all the samples of limestone distinguished or marked as hard rock except the Face-4A. This also means the Face-4A consumes less energy during the comminution among all samples respectively and hence, shows the high rate of grindability.

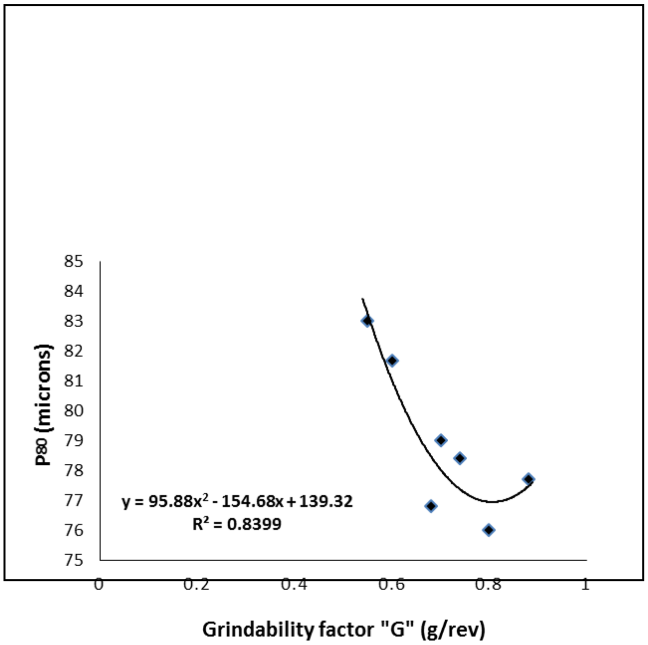
TABLE 3
THE EXPERIMENTED AVERAGE VALUES OF BOND WORK INDEX

On the basis of standard procedures, as shown in Figures 14-15 by increasing the number of grinding cycles with respect to the product size (P_{80}) and work index (W_i) the grindability factor (G_{bp}) decreases.
By Using the graphs, the 80% feed size (F_{80}), 80% product (P_{80})

S#	Sample	Work index (Kwh/t)
1	Face-2B	20.22
2	Face-4A	18.46
3	Face-4B	20.64
4	Face-5A	22.59
5	Face-5B	20.25
6	Face-6A	25.06
7	Face-6B	23.06

and grindability factor (G) are taken. The controlling screen is

106µm (Pf).



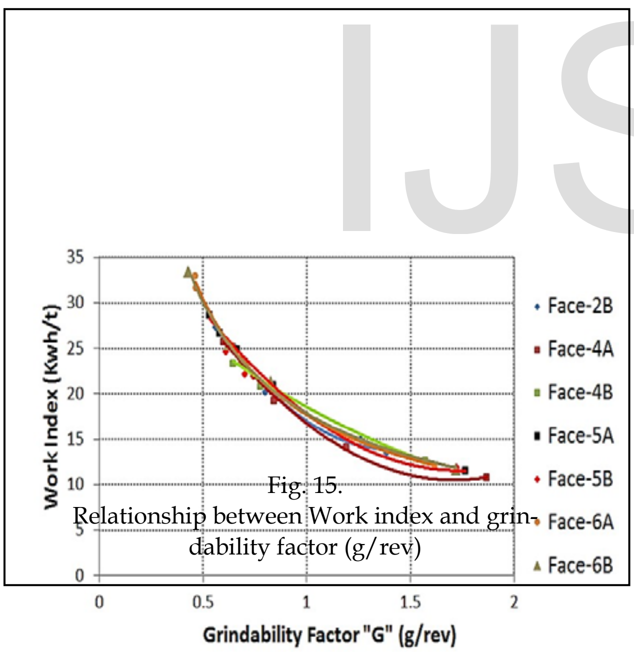


Fig. 15.
Relationship between Work index and grindability factor (g/rev)

4. CONCLUSION

In the present work, attempts have been made to calculate the work index (W_i) having a different samples of limestone including Face-2B, Face-4A, Face-4B, Face-5A, Face-5B, Face-6A and Face-6B were collected from Lucky Cement Limited.

These samples analyzed for Bond work index.
Work index results show that all samples falls under the category of HARD ROCK except Face-4A (W_i <20kwh/t). Limestone of Face-4A is MEDIUM HARD ROCK among all samples. . This clears that work index as well as power consumption increases with the hardness of material.
Among all the limestone samples, experimentally, it has been concluded that Face-4A needed less energy consumption and high grindability rate than the rest of others.
Limestone is mostly used in the Cement Industries for the manufacturing of cement, so it is only the Bond grindability method, which is considered to be more advantageous and hence it gives better output.

ACKNOWLEDGMENT

The authors are thankful to Ahsan Ali Memon, Assistant Professor, Department of Mining Engineering and Dr. Hafeez U Rehman, Dean of the Faculty of Engineering, Mehran University of Engineering & Technology, Jamshoro, for providing experimental facilities for conducting the research work. Similarly, authors wants to convey his thanks to Sikandar Ali Jokhiyo, Mining Engineer, Lucky Cement Limited for providing professional assistance to collect limestone samples in order to accomplish his research task.

REFERENCES

[1] Prasher, C.L, "Crushing and grinding process", handbook, Consultant to chemical and mechanical engineering industry, Linora Technical Associates, John Wiley & Sons Limited, Chichester, New York, 1987.

[2] Kelly, E.G., and Spottiswood, D.J., "Introduction to Mineral Processing", Australian Mineral Foundation, Printed in Australia by Crescent Print, 1995.

[3] Aksit, M.Ö., "Reducibility Properties of Erdemir Samples", Metallurgical and Materials Engineering, Volume 107, Middle East Technical University, 2004.

[4] Weissberger, S., and Zimmels, Y., "Studies on Concentration and Direct Reduction of the Ramim Iron Ore", International Journal of Mineral Processing, Volume 11, No. 2, pp. 115, 1983.

[5] Petruk, W., "Mineralogical Charagteristics of an Oolitic Iron Deposit in the Peace River District, Alberta", Canodian Mineralogist, Volume 15, pp. 3-13, 1977.

[6] Babu, S.P., Cook, D.S, "Breaking, crushing and grinding", SME Mining Engineering Handbook, vol. 2. AIMMPE, Inc., New York, 1973.

[7] W. Cao, "Synthesis of Nanomaterials by High Energy Ball Milling", http://www.understandingnano.com/nanomaterial-synthesis-ball-milling.html.

[8] Bond, F, "Crushing and grinding calculations", Brit. Chem. Eng., vol. 6, pp. 543–548, 1961.

[9] Yap, R.F., Sepulude, J.L., Jauregui, R., "Determination of the Bond work index using an ordinary laboratory batch ball mill". In: Mular, A.L. (Ed.), "Design and Installation of Comminution Circuits", Soc, Min. Eng. AIME, New York USA, pp. 176–203, 1982.

[10] Magdalinovic, N., "A procedure for rapid determination of the Bond work index", Int. J. Miner. Process. vol. 27, pp. 125–132, 1989.

Niaz Muhammad Shahani	Master Student	School of Mines, China University of Mining and Technology	www.cumt.edu.cn
Zhijun Wan	Professor	School of Mines, China University of Mining and Technology	=
Abdullah Rasheed Qureshi	Master Student	School of Mines, China University of Mining and Technology	=
Muhammad Ali	PhD Student	School of safety Engineering, China University of Mining and Technology	=
Naseem Ali	Master (Completed)	Manufacturing, Department of Mechanical Engineering, Mehran University of Engineering and Technology	www.muet.edu.pk