REMOTE QUARRY MANAGEMENT

Authors: S S Rawat & P K Sarkar

Holtec Consulting Private Limited, Gurgaon

Remote Quarry Management is an important component of the cement manufacturing process. Quarry Planning & Optimisation, monitoring and effecting improvements in day-to-day mining operations are pre-requisites for sound and scientific Quarry Management practices, which can lead to optimal exploitation of the deposit, judicious blending to enable usage of low grade material ensuring mineral conservation & longevity of the deposit, cost optimisation, etc.

It may not always be feasible to monitor quarry operations on a close watch basis by continuous physical presence of Quarry Management experts but the operations can be monitored remotely. ***Remote Quarry Management*** utilises the latest IT enabled services coupled with state-of-the-art mining software to monitor quarry operations and take key decisions from a distant location on a day-to-day basis.

This paper illustrates the application and benefits of Remote Quarry Management carried out in a cement plant quarry located in North Africa. The study could effect significant achievement in optimised raw material exploitation resulting in longevity of deposit life and low cost of limestone production.

1 INTRODUCTION

With the limited availability of raw material resources, increasing mining constraints, stringent quality requirement, tighter planning schedule and stiff competition in price of end product, exploitation of raw material is becoming more cost competitive. Innovation in mining methods and technology that are to international mining standards and “best practices has become vital. It is evident from the past history that during down turn, the pressure is on reduction on cost, so it is better to prepare for this rather than wait.

Even in efficiently operating mines, significant improvement can be achieved by optimal exploitation of the deposit, judicious blending to enable usage of low grade material ensuring mineral conservation for longevity of the deposit and cost optimisation by applying latest IT enabled technology available in mining field. Holtec Consulting has carried out remote quarry monitoring for limestone mine of a cement plant located in North Africa. The objective of the study was:

- Remotely monitor mining operations on weekly basis
- Guide and suggest optimum extraction technique on a weekly basis
- Provide flexibility in mining operations

- Guarantee steady supply of homogenized material
- Minimize human dependencies and biases
- Ensure savings in mining costs
- Most importantly, extend deposit life

2 REMOTE QUARRY MANAGEMENT

Present mining industry believe in conventional method of local mine management and increasingly finding themselves constrained with lack of qualified staffs. Besides strengthening skilled workforce **Remote Quarry Management** offers various benefits. The prime objective of remote monitoring is to shift the control centres to a remote location where the quarry operation can be monitored remotely by experts.

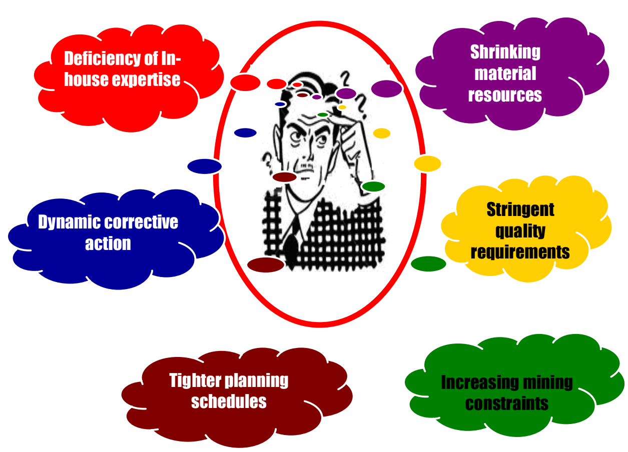
Remote monitoring tools viz., Remote Sensing, Global Positioning System, Robotics are available now a day for safe, efficient and economical mining operation from a centralised location with limited manual intervention. "Remote Quarry Management" in line with similar approach, is a combination of various IT enabled tools coupled with state-of-the art mining software's to optimally manage the deposit as low as on weekly basis from distant a location, satisfying the long term objectives of "***Maximization of life at Minimal cost of Production***".

Where We are Now (Conventional Approach)	**Where we Should be in the Future (Adopting IT enabled tools)**
Work force and managers are mentally locked to existing short term practice. Global objectives are ignored Little coordination between planning and operation Decision making structures are manifold Potential work force is located at site Manual planning and scheduling with little knowledge about objectives Very limited knowledge about the mines and deposit at organization level	Control and management of mine from a remotely located platform using emerging IT tools. Global objectives are reflected in short term model. Synergy between planning and operation with enhanced coordination and knowledge base. Streamlined and effective coordination by reduction of redundant management. Potential leaderships and staffs are located in ideal location independent from mines Instantaneous planning from remote location with minimum efforts Sharing of knowledgebase at organizational level

3 WHY REMOTE MANAGEMENT

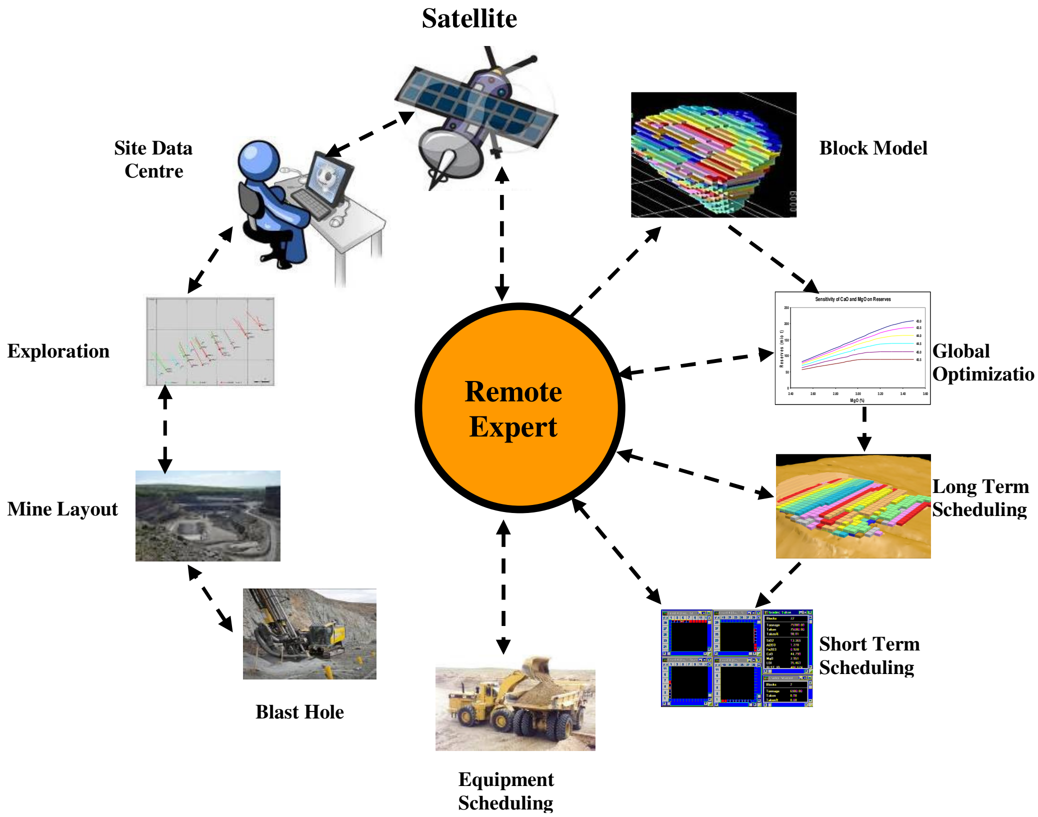
Strict regulatory requirement, inflexibility in mining operation, lack of in-house expertise, limited resources, shrinkage in material resources, increasing mining constraints, tighter planning schedule and dynamic corrective actions, practically made it difficult for mine planner to meet the objectives of quarry management effectively.

"**Remote Quarry Management**" with expertise and versatile tools can efficiently manage the quarry in quick time from a centrally located platform with expertise intervention.



4 WHAT IS REMOTE MANAGEMENT AND HOW IT IS IMPLEMENTED IN THE FIELD

Remote Management is a highly secured web based data sharing and management tools with amalgamation of various IT tools and mining software's to analyse and support actual mining activity in field from a remotely located centre. This helps to monitor the mining objectives on a close watch basis and provides quick solution to mine planner apart from sharing strategic information with the entrepreneur.



Remote Management involves:

- Application of optimization and expertise services on weekly basis from distant location through remote quarry scheduling
- Takes into account instantaneous corrective measures by timely expert intervention
- Provides flexibility in change of schedule during unavoidable circumstances with multiple scheduling scenarios
- Regular and continuous updation of deposit inventory
- Monitoring of equipment uptime
- Savings by providing optimal layout and avoidance of expert visits

5 BENEFITS:

Remote Management benefits a Quarry in terms of productivity, saving in cost and knowledge base at various levels in multiple ways. The potential benefits are as follows:

Level	Short Term	Long Term
Mining Engineer	▪ Quick and alternate solution ▪ Flexibility in operation ▪ Timely and Detailed analysis ▪ Avoid human biasness	▪ Efficient operation management
Manager	▪ Evaluation of Multiple Scenario ▪ Elimination of dedicated manpower	▪ Optimal use of deposit ▪ Streamlined quarry layout ▪ Continuous updation of inventory ▪ Better control over deposit
Company	▪ Saving in operating cost ▪ Continuous updation of inventory	▪ Enhanced equipment life/ uptime ▪ Enhanced Deposit Life

6 METHODOLOGY

The various components contributing to remote quarry monitoring are:

- Inventorization of deposit by construction of Deposit Block Model
- Quarry scheduling & Optimisation considering various sort of parameters viz. mining constraints, Raw Mix design, Equipment capability etc
- Preparation of Blast hole Model for short term scheduling
- Weekly planning considering pile parameter and alternate schedule
- Feedback and continuous updation of Block Model in every 5 years based on feed back / additional exploration

The steps involved in Remote Quarry Management is presented through flow chart in **Chart No 1**

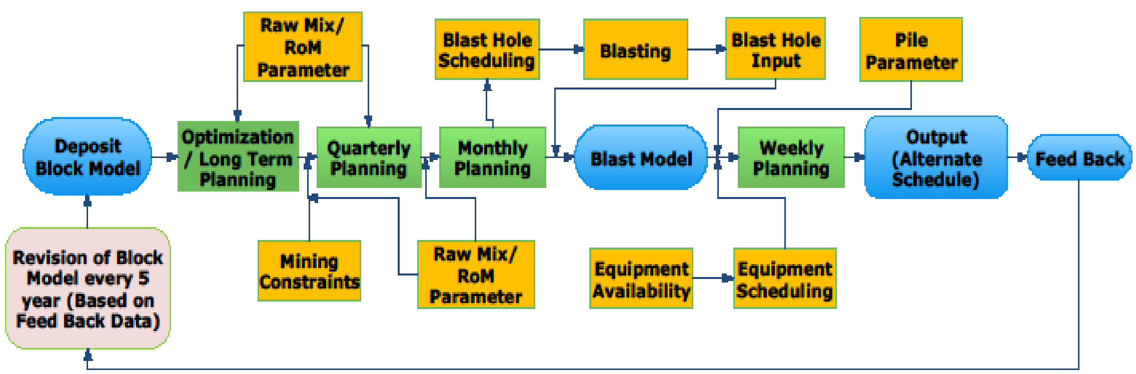


Chart No. 1 Steps in Remote Quarry Management

The steps are broadly elaborated in the following para:

6.1 Deposit Block Model

Deposit Block Model is the digital form displaying inventory of the deposit in smaller mining units. A deposit block is nothing but the smallest form of the deposit which can be reliably estimated (both in terms of Quantity and Quality) based on the available exploration data. The block model created by SURPAC/ DATAMINE (as shown in **Fig 1**) not only provides exhaustive information about the deposit but it forms the basis for mine scheduling offering flexibility in mining with multiple blending options.

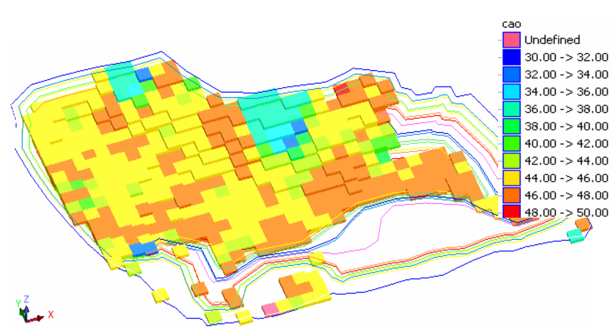


Fig 1 Deposit Block Model

6.2 Deposit Inventory

Grade-tonnage relation generated from block model (as shown in **Fig 2**) using powerful softwares viz. GEOSTAT and MINRES reliably describes the deposit inventory at various cut-off grades. While the **Grade Tonnage (GT)** curve displays the availability of material at various cut off grade and helps mine planner to understand the soundness of the deposit, **Grade slice plan** (ref. **Fig 3**) on the other hand, outline the distribution pattern of the grade at various levels and parts of the deposit, indicating approach for planning.

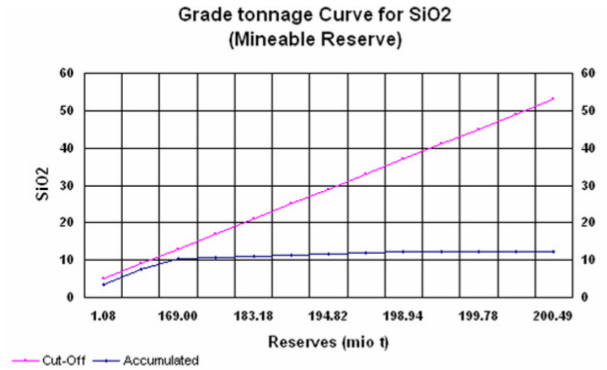


Fig 2 Grade Tonnage Relation

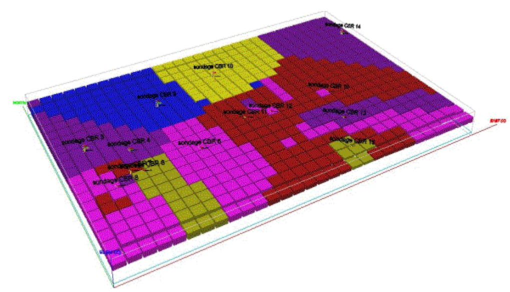


Fig 3 Grade Slice Plan

6.3 Global Optimization/ Sensitivity Analysis

While Grade tonnage relation gives an idea of the deposit inventory, QSO (Quarry Scheduling Optimization) portrays the potentiality of the deposit, where, multiple grade and mining constraints put together determines the maximum possible reserves with minimum rejection. An extensive and versatile sensitivity analysis could be drawn (as shown in **Fig 4**) from the block model and help management to decide upon the long term mining strategy. Global optimization benefits in maximization of deposit life by optimization of low to marginal grade material and saving in cost by minimal rejection

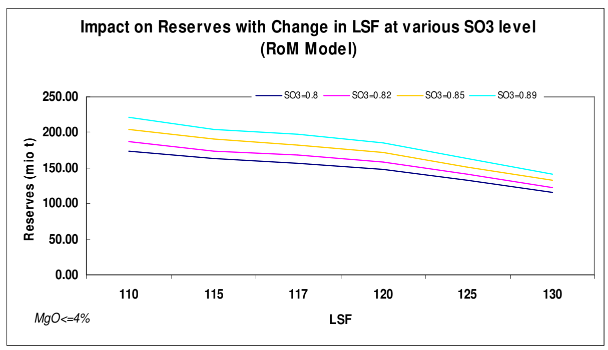


Fig 4 Sensitivity Analysis

6.4 Long Term Planning

The lack of a long term direction or strategy and information to support quality long term planning is a big challenge in today's race of mining. With increased pressure to meet rising demand for resources, it is imperative for mine planning departments to ensure that operational plans do not jeopardise the long term potential of mines to suit short term production targets.

Long term plans are basically the strategic actions to be delivered in phase wise manner and the purpose of long term planning is to ensure the enduring sustainability of the company's mining activity, achieving economic profitability. **Remote Quarry Management** uses the latest optimization technique with artificial intelligence and is beneficial to the entrepreneur in the following ways:

- Global objectives are transferred in 5 yearly plans
- Impact of change of parameters on plan and its global impact could be monitored by experts and subsequent corrective measures can be taken remotely
- Flexible planning with Expert Intervention
- Minimization in cost of production by formation of most optimal and streamlined layouts
- Industry know how and expert knowledge base help in optimal long term planning

6.5 Medium Term Planning

Having a long term plan it should not just be stored on the mine planner's bookshelf. It needs to be reviewed at least yearly in conjunction with the business planning and budgeting process and where major change is identified it needs to be revaluated for long term effect.

Further in the Indian mining context, where apart from variability in quality, seasonal changes also have impact in mine planning, a yearly review may not be adequate enough to be implemented rather a more realistic plan giving due regard to seasonal impacts need to prepared and implemented without hampering the long term objectives. **Remote Quarry Management** can seamlessly do the job and assist mine planner remotely in the following ways:

- Process quarterly and yearly plans instantaneously with change in mining parameters, budget or plant requirements
- Prepare multiple plan for various season without deviating long term objective
- Analyse and the global situation at any point of time
- Guide mine planner in sequence of mining at minimum cost of operation
- Savings in cost by minimizing unplanned mining

6.6 Short Term Planning

There is an increasing need within the mining industry to ensure that the strategic intent of the company is successfully executed at an operational level of the business. The short-term planning process, typically the last step in the planning cycle, essentially translates the operational objectives of the company into an executable plan.

Remote Quarry Management with the help of multiple skill base and combination of software's is very much effective and handful for a mining engineer to plan even up to weekly production level using blast hole model and is advantageous in the following ways:

- Multiple weekly/ monthly schedule with its pros and cons
- Steady and homogeneous supply of mined product
- Geo-coding of schedule to make it user friendly and easy identification in the field
- Cost optimization by reduction in corrective consumption by planning at raw mix/ pile level
- Equipment scheduling to match the production requirement in most cost effective ways
- Saving by lead balancing
- Planning for micro mining constraints

6.7 Data Validation and Model Correction

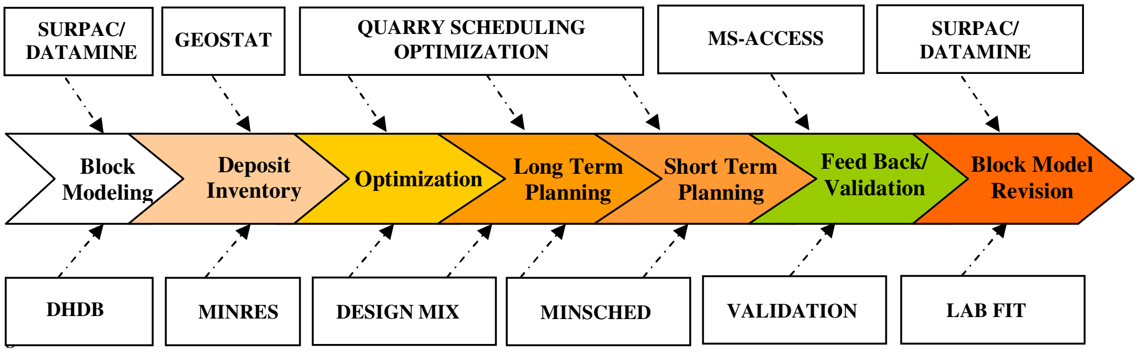
"*A prediction can never be actual*". Often in the mining industry, it is found that the block model predicted from exploration bore hole differs from actual quality derived from blast hole, leading to deviation in mining. This may be attributed to various reason viz.,

- The complete block is not excavated
- Floor RL is not maintained
- The analytical instruments used are different
- Representative chip samples are not collected

Remote Quarry Management uses PHP based validation software to validate the predicted quality with actual blast data and a trend is established by curve fitting software. With a valid trend, the block model data is tested for revision and revalidation on a regular basis till the deviation is minimized.

7 TOOLS:

Highly Secured web base data sharing is behind the success of Remote Quarry Management where data from various mines/ deposits are stored on weekly basis for its analysis and reporting by expert bodies. Following tools are used at various phases of Remote Quarry Management:



8 Inputs for Remote Quarry Management:

- Exploration data (Topographic Plan, Geological Plan, Drilling Data)
- Exploitation Data (Updated Quarry Plan, Feed Back for Blast quantity, quality and location)
- Quality Control Data (Viz., Blast Hole Sample results with location, Corrective data)
- Equipment Data (Equipment wise Run Hrs/ Break Down Hrs, Availability, Utilization, MTBF/MTTR, Fuel Consumption, spares consumption etc.)
- Plant Data (Target LSF, SR, AR, quality parameters and Target quantity)

9 CASE STUDY

Remote Quarry Management carried out in a cement plant quarry located in North Africa.

The mine under reference belongs to Cement Company located in Ethiopia in North Africa. The rock types encountered in the area are marl, limestone, gypsum and sandstone. The limestone is overlained by marl and thin gypsum bands at the top as shown in **Fig 5**.

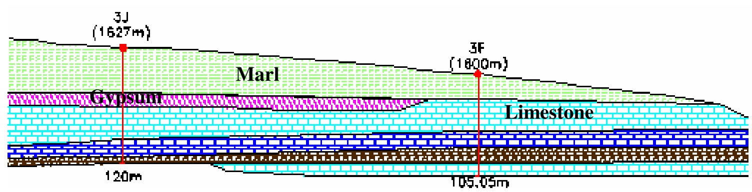


Fig 5 Typical Cross Section

Detailed geological investigation of the area comprising of topographical survey, geological mapping, diamond core drilling, sampling and sample analysis were carried out. **HOLTEC** has subsequently evaluated the deposit by application of SURPAC software and a deposit Block Model was constructed. The deposit block model has established the availability of marginal grade quality marl and high grade limestone within the quarry area. The salient outcome of deposit block model is given in **Table-1**.

Rock Type	Reserve (mio t)	Quality									
		LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	Cl
Marl	81.89	31.66	17.76	4.79	2.30	36.53	1.98	1.16	0.03	0.91	0.01
Gypsum	24.66	23.94	9.72	2.56	1.32	35.48	2.55	0.29	0.03	16.99	0.01
Limestone	108.58	37.8	8.16	1.30	1.06	47.02	1.08	0.35	0.16	0.91	0.01

Table 1 : Outcome of Deposit Block Model

- Marl is low to marginal grade and can not be used independently for cement manufacture and if not used shall form part of reject, resulting into huge increase in limestone raising cost or loss of mineral
- Limestone is high grade and would require blending of substantial amount of argillaceous material to arrive at a suitable cement raw mix

- Limestone along with marl is poorer in quality for manufacturing of quality clinker
- Above 108.58 mio t is recoverable at an OB ratio 1.02 (REJECT/ LIMESTONE). Out of the above about **89 mio t** of mineable limestone is estimated excluding 19.58 mio t in the constraints.

9.1 Quarry Scheduling & Optimisation

In consideration of above Quarry Scheduling & Optimisation software was used to achieve the following objectives:

I. Maximum use of low grade marl to reduce the reject ratio

II. Minimum use of high grade limestone to increase the longevity of the deposit since the reserves are limited

III. Minimise the cost of production

9.2 Sensitivity Analysis

Apart from LSF, SR and AR (the three major ratios which play the important role in cement manufacturing), SO_3 is a sensitive element as limestone is rich in SO_3 due contact of gypsum. A sensitivity study (i.e., impact of the all above ratios and SO_3 over reserves and OB ratio) was carried out as presented in **Fig 6**

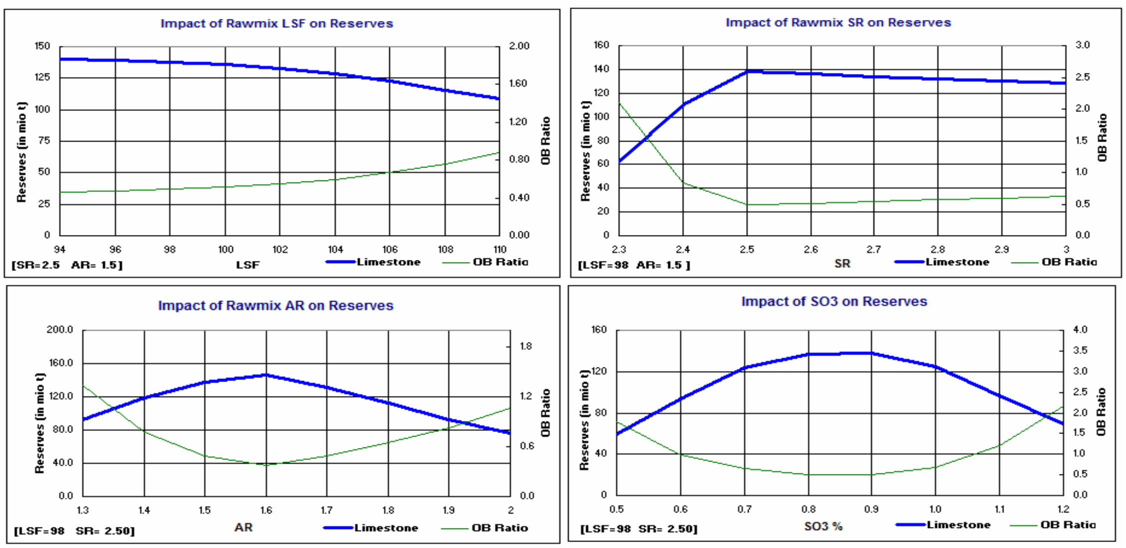


Fig 6 Sensitivity Analysis

As depicted in the above graphs, from sensitivity analysis following is illustrated:

- By lowering LSF in the raw mix, the reserves enhances by optimization of low grade marl and it is possible to optimize about **48 mio t** of marl in the process. On the other hand Over Burden (OB) ratio of limestone reduces.
- SR has a positive impact on reserves i.e., reserves enhances with increase in SR upto a maximum value of 2.5.
- Gain in reserves by increasing AR upto 1.6 and maintaining SO_3 upto 0.90 in the raw mix shall fetch better reserves

Sensitivity analysis demonstrates the global situation at various scenarios. However, to arrive at applicable parameter for deposit optimization, a raw mix study has been carried out maintaining LSF at around 98, SR at around 2.5, AR 1.5 and SO_3 (0.96 at RoM) and it is established that quality clinker could be manufactured by use of 94% RoM (Limestone 65% + Marl 35%) and 6% Basalt .

Global optimization with above parameters could enhance the reserves by optimization of low grade marl and reduces the OB ratio as well as cost per t of limestone as may be seen in **Fig 7**.

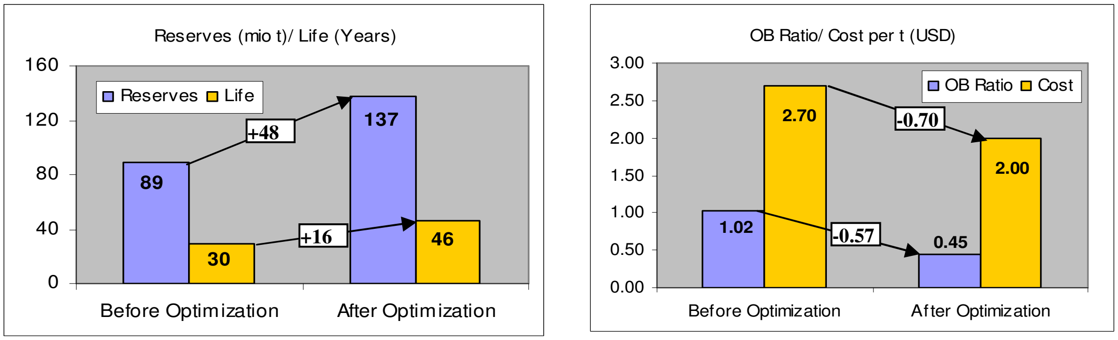


Fig 7 Gain by Optimization

By optimization there is a saving of approx. ***2.10 mio USD*** *per annum just by reduction in rejection. The additional life shall further add to the saving over additional 16 years.*

9.3 Quarry Scheduling

Based on long term schedule prepared in 5 year block over Deposit Block Model, area for 1^{st} year, 2^{nd} year, 3^{rd} year, 4^{th} year 5^{th} year of mining operation was identified. The area for 1st year was further bifurcated in Quarterly mining operations giving due regards to seasonal impacts. To start with mining operation two potential areas with limestone exposure or minimum marl as over burden have been selected. The initial 5 year schedule prepared is given in **Table-2**

Schedule Period		Planned Qty (mio t)			Planned Quality		Avg. Lead (km)	Planned Equipment	
		Limestone	Marl	Reject	LSF	SO_3		Shovel	Dumper
Pre Development		0.07	0.04	0.20	99	0.78	0.40	Hiring	
Year-1	Quarter -1	0.30	0.20	0.50	118	0.96	0.40	3	7
	Quarter -2	0.40	0.10	0.30	124	0.95	0.50	3	7
	Quarter -3	0.60	0.15	0.45	120	0.91	0.50	3	7
	Quarter -4	0.60	0.15	0.50	121	0.90	0.50	3	7
Year2		2.07	1.03	2.53	127	0.87	0.75	3	8
Year3		2.08	1.04	1.32	121	0.93	0.75	3	8
Year4		2.10	1.05	0.66	125	0.74	1.00	3	9
Year5		2.07	1.04	0.55	128	0.74	1.00	3	9

Table-2 : Quarry Schedule

The schedule is prepared considering the following objectives:

- Optimal utilisation of marl and high grade limestone
- Maintaining of average OB ratio within a block of 5 years
- Optimal lead from mine face to crusher and dump area

During 5 year plan, it is planned to work from two locations to maintain quality parameter and take advantage of profile to expose high grade limestone. In the process, in the initial years more rejection planned and reconciled with global rejection within a block of 5 year.

The schedule was discussed with mine operating management for its validation and has been implemented in site under the guidance of Holtec's Specialist. The schedule has lead to flexibility in mining, lead balancing, minimized frequent shifting of HEMM.

9.4 Blast Hole Scheduling

To facilitate mines department one step ahead Holtec has initiated the IT enabled web based data sharing tool. By this alternative blocks for weekly production requirement were identified based on the quarterly schedule prepared by quarry scheduling & optimisation. Blast hole planning was done with geo coding of respective boreholes within a plan period. The selected area(s) was drilled by DTH drilling and the chips generated during drilling was analysed for chemical analysis. The chemical analysis were shared with HOLTEC through website in excel format. The following actions were taken by HOLTEC's Expert remotely from its office.

- Weekly and monthly blast hole planning/ sequencing, Drilling Inventory, Lead Balancing and planning for micro mining constraints
- Short Term blast modeling based on blast hole data and Geo coding of model for interactive use
- Scheduling with alternate production plan on weekly basis meeting Pile requirement
- Analysis of equipment, health, availability and capabilities for production
- Equipment placement scheduling with weekly production and development need
- Outputs in the form of production plan and geo-coded plans for implementation at site.
- *The working plan is developed as a KMZ file to view in Google Earth for real time feeling*

9.5 Data Validation

As a part of quarry management, Holtec is in the process of continuous validation and updating of block model from feed back data received from the site. By this process, the feed back data for each blast is recorded at site as per prescribed format and uploaded in the web site for Holtec's Expert analysis. By this process the client is availing following benefits on a regular basis:

- Deviation in planned and actual quality is measured from feed back data
- Bottleneck areas identified for future planning, forecasting of constraints
- Validation of model for predictive qualitative assurance for future planning
- Measure the degree of deviation from planning verses actual operation, its Impact and corrective measures

9.6 Measurable Benefits availed

- Enhancement in Life by **16 years** by gain in reserves of **48 mio t**
- Reduction in overburden ratio by a factor of **0.57**
- Saving in terms of cost by about **0.70 USD** per ton of limestone. Recurring saving over additional 16 years of life
- Benefits in terms of material handling/ dumping
- Reduction in excessive manpower
- Saving in drilling cost, mining equipments, fuel consumption etc
- Optimized and streamlined quarry layouts maintaining global objectives

10 CONCLUSION

The present demand in the cement market and depleting good quality resources, forcing the cement industry to look for more flexible, cost effective and smarter business model. Limestone being the major commodity for cement, it is imperative to pay maximum attention to achieve the goal. Mining is a dynamic scenario and any change in the market shall reflect this industry first unless it is timely managed. "Remote Quarry Management" gives a complete solution to all the aspects of mining, optimization, scheduling, quality control and monitoring from remote location with expert intervention and fits most to the future business model of mine management.

The application of Remote Quarry Management on a cement plant in Ethiopia have shown that low grade marl occurring at the top of limestone forming overburden could be managed in most optimal and cost effective way. Apart from the above study also reveals that continuous involvement of remote support has resulted in generation of streamlined quarry layout.

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