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Rigger Implementation to Enhance Mucking Productivity of Continuous Loader at Rishikesh Karanprayag Railway Tunnel Project Pkg-02, Byasi Uttarakhand India- An Innovative Approach

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Abstract:- A Continuous loader called Haggloader 7HR is deployed in Rishikesh Karanprayag Railway Tunnel Project Pkg-02 for safe and optimal loading of muck from the blast face. To counter growing operational cost and inefficiency of tunnelling construction, continuous loader seems to be a game changer for muck loading for smaller diameter tunnels. Muck loading is a cyclic process where an average quantity of 60 to 90 $m^3$of muck is being generated after every blast operation. Due to the rotation constraints of normal excavator in smaller diameter tunnels, continuous loaders seem to be the best option available.

This paper describes the background of project execution with detailed roadmap and excavation process employed for space development. the major issue arises while deploying continuous loader is the approachable height of loading, on the ground facts describes the issue where haulage approach is out of reach. Haggloader reaches on 1/3rd of the total height of haul from the base. Approachable loading height is always an issue when it comes to loading. It was also observed in case of Continuous loader conveyor that the total approachable height of conveyor from the base of haulage was around 1 feet. Due to which loading capacity was deeply affected. To counter the same Riggers has been implemented at the rear end which lifts the Continuous loader 1 feet from the ground, in turn lifts conveyor 3 feet from the base of the Haul is the state of an art. A complete set of data on monthly basis before and after implementation has been recorded to map the muck loading capacity of Continuous loader. On the basis of regression analysis total improvised efficiency of Continuous loader after Rigger implementation with excellent correlation factor R^2= 0.9987 and R^2=0.7133 before implementation was recorded. Production per unit time has also been described in this paper. The improvisation with recorded data has the potential to rapidly improve loading capacity of continuous loader.

Keywords:- *Continuous loader, Rigger, Excavation, NATM, continuous loading, Parametric Analysis.*

I. INTRODUCTION

India is the new venue for tunnelling and underground space development where rapid urbanization has increased the need for transportation and infrastructure projects. A considerable amount of space development work has been continually in process for hydroelectric, roadways, railways and irrigation sector. To develop and improve connectivity in rural areas most of these projects are located away from urban clusters. Also, such projects are having major economic potential [1]. Indian railways have proven to be more economical and sustainable for long run and major distance coverage in terms of connectivity. India has managed to stand on 4th largest railway route network in the world with a total length of 126,511km [2].To extend the roots of mass movement, Indian railways has initiated several projects in its Himalayan region that commits a huge demand of rock excavation.

Excavation in Himalayan terrain has always been a challenge for civil infrastructure units owing to inclement weather conditions along with difficult geological conditions and focus on preserving the integrity of nature and rock mass. One of the newly launched yet most challenging infrastructure development projects to establish a rail link between Rishikesh to Karanprayagis being constructed by Larsen and Toubro Heavy Civil Infrastructure IC. The Package-02 (Pkg-02) of the Rail Vikas Nigam Limited (RVNL) is being excavated by New Austrian Tunnelling Method (NATM) method over a length of 14.653 km. The project road map initiates from Shivpuri – Adit 02 – Gullar – Adit 03 and ends with Byasi. The tunnel length is executed through16 faces from Shivpurito Byasi. To get more into the routes Fig 1 shows the detail execution of plan for RVNL Pkg-02.

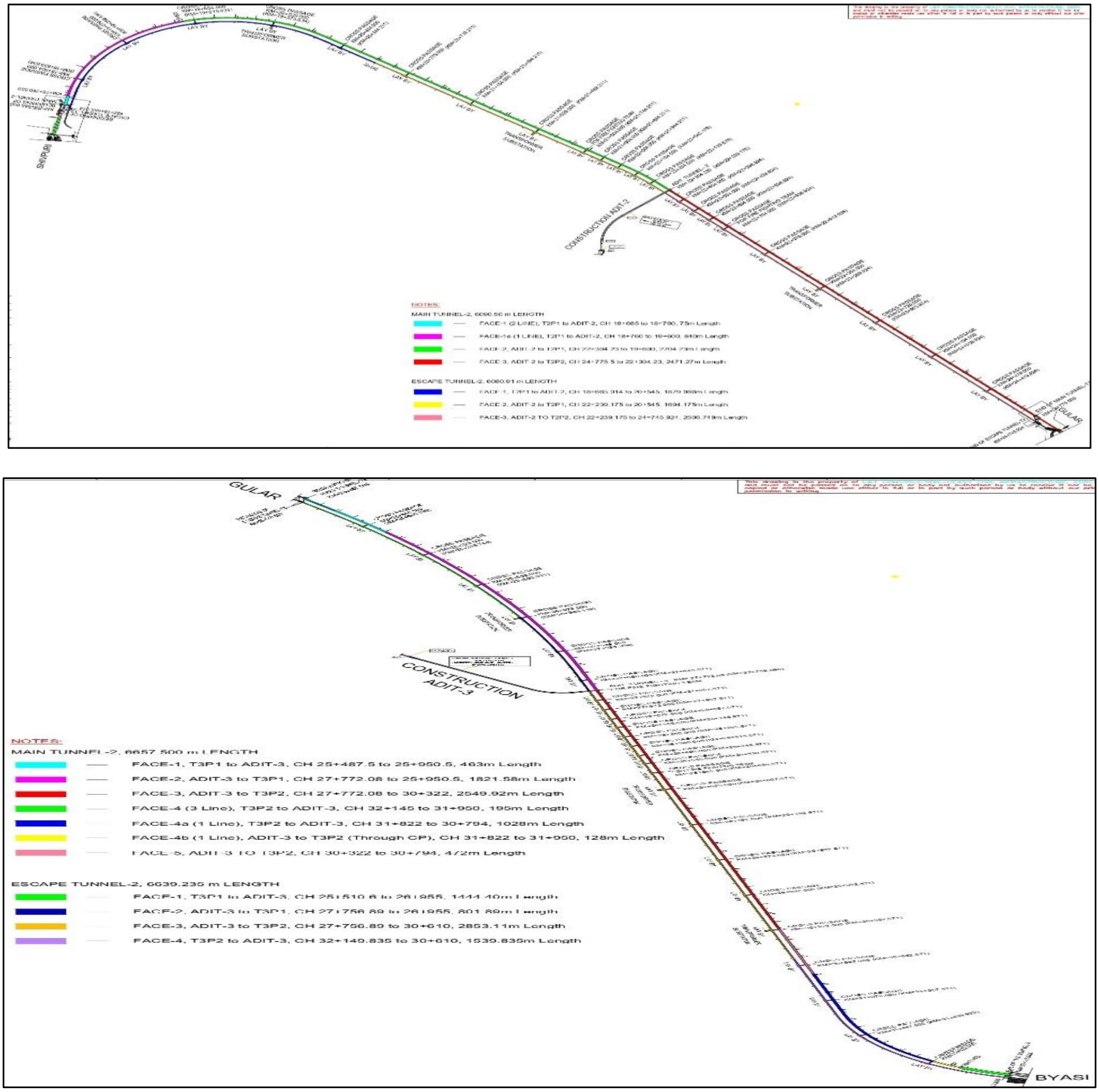

Fig.1: Detailed tunnelling map of Pkg-02 Rishikesh to Karanprayag rail link

As it is evident from the planthat length of escape tunnel is shorter than main tunnel, cross passages have been allotted with respective interval of chain age to keep the environment safety and mobilization of assets into account. Tunnel area is facilitated with sump well and pumping drainage system to avoid unnecessary clogging of mud between roadways. These measures are employed to have ease while mobilizing assets and also to keep the environment clean. Ventilation is a priority and a safety measure as it allows to maintain the oxygen levels and reduce harmful gases in underground structures.

Drill jumbos with automatic and semi-automatic machines are deployed for rock bolting even in RVNL Pkg-02 project.

II. NATM PHILOSOPHY

The NATM- New Austrian Tunnelling Method was put forth by L.V. Rabcewicz in 1950 [3].Underground structures stand to be a load bearing structure in NATM Technology in case where activation of ring like body of supporting ground or rock mass is the key factor of excavation. Major activity involved in NATM is blasting. It is highly flexible and adaptable to changing ground conditions and also in regard to the tunnel cross section or intermediated section [4]. The total cost associated with drilling and blasting is low as compared to mechanical excavation (TBM) with constant productivity. Engineers can plan the execution of project according to the productivity requirement and budget. To explain more precisely Table 1 shows the basic line up applicable for the process.

Sl No.	Major Area	Sub Area
1	Theory	Rock and Soil Mechanics
2	Support	Utilizing self-support capability of surrounding rock
3	Main Support	Bolting and shotcrete
4	Controlling measure	Deformation and loosing of parent rock
5	Design	Guided design of tunnel construction as per respective rock class
6	Machine	Deployment of machine for roof bolting and shotcreting

Table 1: Basic line-up for NATM

Drilling and blasting is a proven technique for excavation. In present case 60$m^3$to 90 m^3muck of escape tunnel is excavated in a single shift or a blast. Management of the blasted muck is a major concern in the project. Many efforts have been taken to automize the technique where broken rock can get mucked automatically by front-end loader which moves the load by a conveyor to a hauling system. Automated loading technique which leads to mucking is the need of hour to eliminate delays in tunnelling. Continuous loading technique is found to be the only solution which can improve mobility of drilling machines, development of roadways to decrease total time of transitions can directly reflect on the productivity. To employ such technique in a heavy civil infrastructure project will become a game changer. A continuous giant loader called Haggloader 7HR by EPIROC is deployed in the project under discussion.This continuous loading system has proven to be the highly productive and economical when compared to other loading methods in small to medium size drifts. Its smart design and compactness can lead the loader to eliminate loading bays thereby avoiding time loss in subsidiary operations. Its manoeuvrability can lead to load hard and more abrasive rock boulders from the face and can easily be matched with traditional mining conditions. To get more clarity in case of loading the detail design of Haggloader 7HR with different parts is shown in Fig 2.

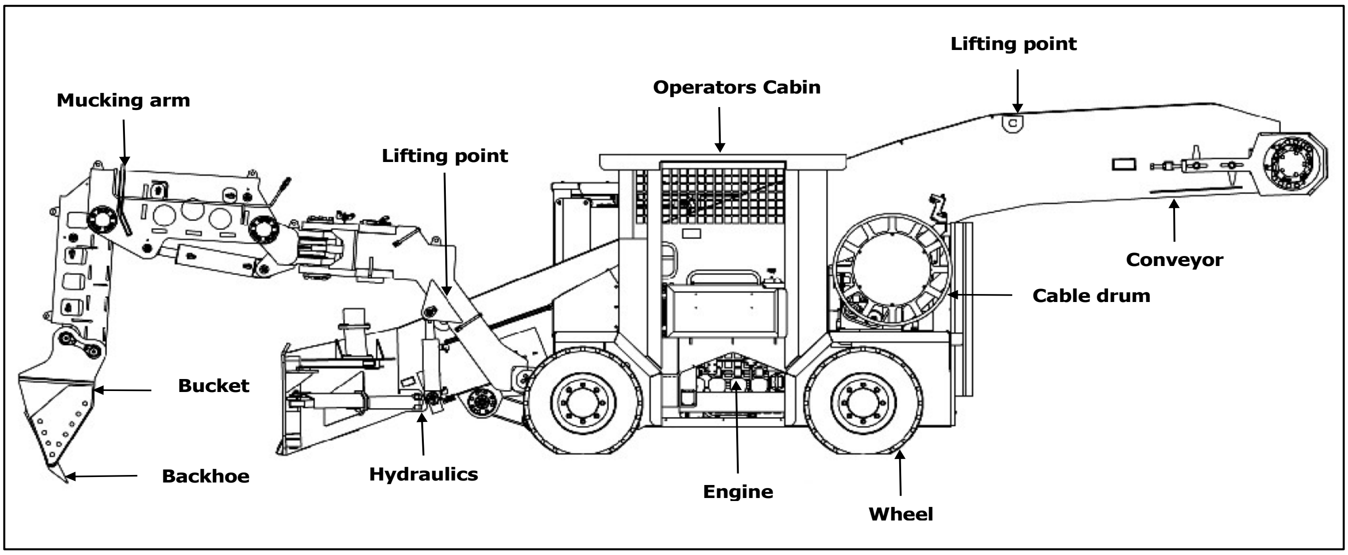

Fig. 2*:* Detail design of Haggloader- continues loader

Continuous loader has three major parts such as an arm system, chassis and conveyor. Through the system of digging arms, dozer blades and a conveyor is shovelled from the blast face onto the loader's conveyor to the dumpers den. The whole body of conveyor hinged from the rear end manages to enter at the rear end of the haul where dumping is carried out. The continuous process carried out with the help of roller to actuate the conveyor with certain distance from the bottom of the haul. This conveyor system can be lowered or raised as per the hauling height. A sturdy roof and cabin can protect the operator's compartment from rock falling. Loader can also available in different attachments as per the requirement such as a two-blade digging system and backhoe. Machine is controlled by crab steering can been driven diagonally where both pairs of wheels can be steered independently. Hydraulically actuated attachments can lead a more ease in case of loading the debris dynamically. The controlling of arms is totally dependent on hydraulic cylinders. The loader is equipped with integrated sprinkler system to counter the dust and explosive gas in the surrounding. At the same time cleaning the tunnel ground is a prior duty, barring at the same time is essential in such case. The backhoe system is more useful for having optimized bucket design. Mucking bucket is itself capable to remove dangerous and loose rock from the face. For tunnelling in heavy projects, the deployment of Haggloader 7HRis best suited which comes up with backhoe configuration of1.2 m^3/minhigher loading capacity. Table 2 shows the details parts description with different configuration attached.

Sl No.	Major Head	Class	Description
1	Technical design parameters	Length	10150mm
		Width	2200mm
		Track width	1880mm
		Wheel base	2000mm
		Turning radius	6500mm
		Weight	14100kg
2	Mechanical parameters	Cylinders	Turbocharged 4cylinder
		Power output	54.7 Kw
		Max torque	250Nm
		Displacement	3620cc
		Compression ratio	1:8
		Transmission type	Hydrostatic
3	Machine insides	Axle type	212
		Wheel rims	6.5 x 15
		Tyre	8.25 x 15
		Tyre pressure	9kg
		Brakes	Wet disc
		Service brakes	Hydraulic with 2 circuit
		Steering angle	40º and 27.5º
4	Muckingsystem	Capacity	$1.2m^3$/min
		Stability/ Inclination	Must not exceed/ permissible limit 8º - Longitudinal 5º - Lateral

Table 2*:* Technical Background of Haggloader after Epiroc. [5]

Table 3 shows the broad specification associated with loader. Design parameters gives us the overview of loading system with basic outline. Mechanical parameters give the broad idea of functioning of the machine on which performance is dependent. Similarly, machine insides provide us the complete guide of momentum. The most important is mucking system where stability plays an important role. Stability varies from machine to machine where Haggloader comes up with 8ºlongitudinal inclination with 5º in case of lateral. Continuous loading gives many benefits in regular cyclic time, like maintain the project time line by reducing mucking time and to clear the face fornext activity. Following Table 03 shows the loading efficiency and working profile of a continuous loader

Sl No.	Head	Class	Remark
1	Loading	Capacity	It reduces cyclic time between trips which reduce the fuel consumption, eliminates essentiality of loading bays
2	Operation	Electric	Due to electric operation implementation, it reduces ventilation investment associated with total economic cost
3	Power source	Electrical	Cut-off diesel consumption totally as the process is electrically driven
4	Environment	Green tunnelling	Pollution free environment contributes eco-friendly
5	Position	Stationary	It reduces cycle time as compared to traditional process
6	Safety	Operator	Sturdy roof and operators cabin allows safe working environment

Table 3: Working conditions of Haggloader modified after [6]

The above table gives us the integrated idea to keep in account while deploying continuous loader. Haggloader comes with a robust and dynamic design compact in nature allows to work in small passages and in tight cornering's. The continuous loader perfectly matches the requirement of mucking in hard as well as mixed ground conditions.

III. HAULING WITH CONTINUOUS LOADING

Hauling in civil and mining industry impliestothe process of transportation of large-scale muck obtained from the excavation process. Hauling in civil projects are empowered by plant and machinery department. The department is responsible to deploy haul as per the requirement. Hauling is dependent on the process of excavation such as in mechanical excavation by TBM locos are employed as a hauling option. NATM process generally deploys dumper to minimize transition time with maximum dumping quantity. To keep the continuous feeding of debris, dumpers are employed in this project. The hauls are mainly work on the basis of trips. The operating conditions of any machine can vary from site to site, the mucking is mainly oppressed in escape tunnel face or in cross passages, with the help of loader conveyoras it is able to fill the haul to a desired volume and later discharges to the specified location. To load the dumpers$10m^3$is set to be the capacity for hauling as per the standard operating procedure. Engineers must have ensured before deploying a loading unit weather it matches the dumpers approach. It is very critical while feeding to achieve minimum spillage and maximum loading in minimum time with seamless movement of loaded and empty dumpers. This will reduce mean time between two dumping cycles of dumpersand also increase the efficiency. Fig 03 shows the Haggloader deployed in Byasi location.

Fig 3: Haggloader 7HR at Byasi location

Actual site scenario of Haggloader 7HRat Byasi location is given from Fig 03. The loading capacity of Haggloader feeds the muck at the rate of 1.2m^3/ min as the hauling standard capacity is set to 10m^3. It will take around 4 to 7 minutes as an actual loading time to feed the permissible limit volume of one dumper. It is very critical for any plant and machinery engineer to select their assets and mark deployment with minimum breakdown. To manage assets is the primary goal for long run with minimal failures. To march on the same plan MAN CLA Dumpers are employed for hauling. The dumper comes with the loading capacity of 13.70 tons. As per permissible limit dumpers can haul around 10 to 11.30 tons of the total loading capacity only. The overall height of haulage unit of a Man dumper is 4 feet. It is not possible to approach a desired height with total mucking capacity. The deployment of Haggloader 7HR pose concern when it cannot reach the desired height and at the same time it takes maximum time to fill 1/3rd of the total hauling capacity. The dumpers have to do extra trips which in turn increase the total economic cost associated with minimum production quantity of the asset. Even if the loading capacity is higher, but unable to approach the desired height, then it will be a disaster to any engineer to plan the economics without any delay towards the daily progress. It is very essential to counter the problem on priority to increase production of hauling as well as loading at the same time.

IV. RIGGER IMPLEMENTATION:ASTATE OF THE ART

Development of modern technologies in different fields such as manufacturing, implementation, space development, transportation, industrial services etc., stimulates the explosion of new concepts and ideas in the field of engineering. To implement any idea first we need to identify the problem. The main cause of implementation is to achieve maximum work in minimum time. Working on the same line, improvisation of total height seems to be the only option to fill maximum muck with total loading capacity of Haggloader. By taking inspiration of lifting systems a flexible Rigger suitable for being embedded on adaptive robust structure has been implemented to improve the total approachable height which eliminates the loading concern arising during mucking.In an account to gain height Table 04 shows the detail problem identification with implemented solution.

Sl No	Head	Problem identification/ implementation	Total Hauling capacity	Capacity filled	Haggloader height approach	Average Production Qty	Average time of loading	Remark
1	Before implementation	Height approach	10 m^3	3.33 m^3	1 feet from the base of haul	96 m^3	3.5-4h	Short boom excavators are preferred over Haggloader
2	After implementation	Rigger employed	10 m^3	9.5 to 10 m^3	4 feet from the base of haul	96 m^3	1.5-1.75 h	Haggloader height approach improvised

Table 4: Case study of Haggloader at site location

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Short boom excavators are preferred over Haggloader to eliminate delay in regular cycle time. The total approachable height before implementation was 1 feet of the total haul length of the dumper which in turn can fill 1/3rd of the total volume. The average capacity of one blast as evident in table can be mucked in 3.5 to 4 h.

The situation is critical when the total cost associated with dumpers based on volume filled and trips when get multiplied which directly reflects the growing economics. Means the cost associated with loading is now increased with extra trips with added working hrs of short boom excavator. To counter the situation and optimize the cost implementation of rigger seem to be the only option in case of loading. Fig 04 shows the innovation and approach to manage loading.

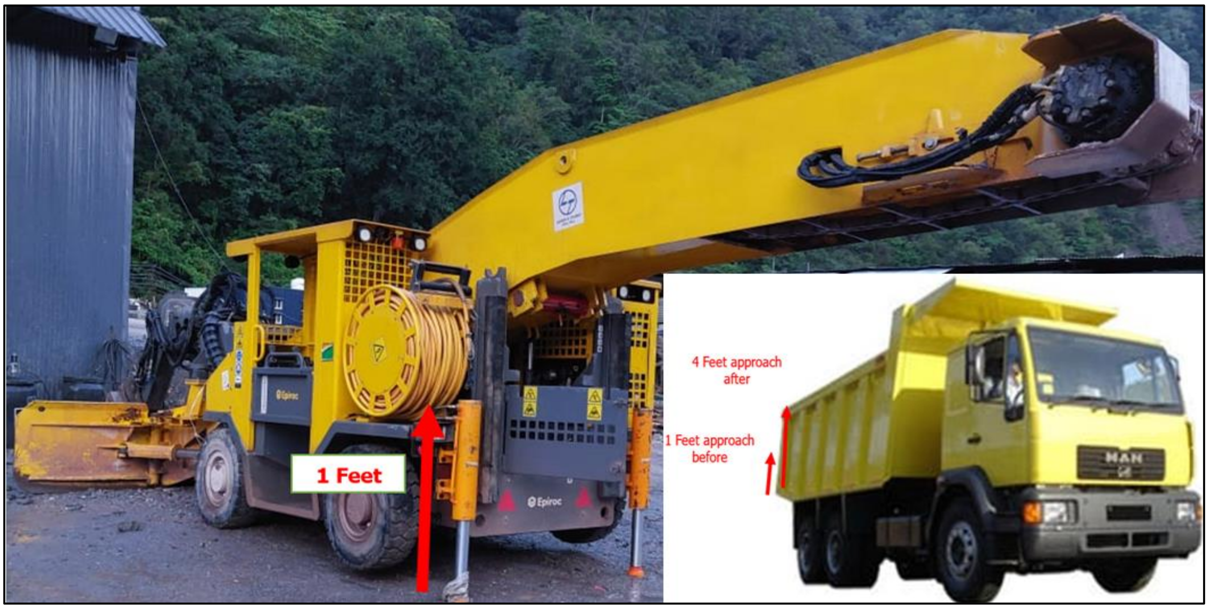

Fig 4: Rigger implementation and details of loading

The riggers are hinged at the rear end of the Haggloader by plate fixed with bolting. Rigger are actuated hydraulically where the hydraulic oil supply is injected from hydraulic dosing cylinder through check valve. To lift the attachment a separate lever is provided in operator's cabin as per desired requirement. As it evident from figure 04 that the approachable height of conveyor is 1 feet from the base of dumper before implementation. The hydraulically actuated rigger lifts 3 feet from the surface which means the total approachable height of conveyor is 4 feet from the base of the haulage. There is a sudden boom in the loading capacity of Haggloader which results in maximum loading output with minimizing the No. of trips of the haulage. This technique decreases the total cost associated for haulage with improved loading capacity.

V. ANALYSIS OF RIGGER IMPLEMENTATION

Analysis is one of the variates where detailed examination of the structure on the basis of outcomes are defined, analysed, correlate and ends with trend plotting. It is very convenient for one to plot the trend on the basis of outcomes and mapped the results as per the requirement. To check the authenticity of implementation, authors have recorded the data on monthly basis before and after implementation of rigger. The total working period 24 hrs was considered as per the shift (Day/Night). Total production of blast muck is considered to be the major factor which influence the mucking capacity of Haggloader. 90 m^3 is recorded as the average production quantity after a blast. On the same line of record hauling capacity of 10 m^3 for one dumper is set constant throughout the month, where No. of trips to haul the muck is calculated by taking production qty and hauling capacity as the base values. To calculate the efficiency of Haggloader loading capacity is set to be the constant value again where it is directly depended upon the mucking trips. It is very essential to calculate total mobilization time when it comes to cycle time measurement, which includes transition time between two dumpers to mobilize. Self-adjusting time of Haggloader at the muck face is also added with demobilization time in account. This all factors are added to produce cycle time to find the total loading time. Toget more engross into the behaviour of rigger implementation a regression analysis is plotted based on the outcomes of monthly recorded data before and after implementation.

The patter of result is predicted byliner regression analysis model on the basis of preceding learning. Once the regression model established a correlation has been set to calculate behaviour of data. Total Hagg loading time is correlated with total production quantity of muckingas shown in Fig 5. In order to assess the impact regression statistical measure which represents the proportion of variance an R^2 is accessed to know the behaviour of rigger. Fig 5 shows the efficiency of Haggloader before and after Rigger implementation The total cycle time of Continuous Loader is correlated with the total production quantity in linear trend which gives R^2= 0.7133 correlation factor before rigger implementation.

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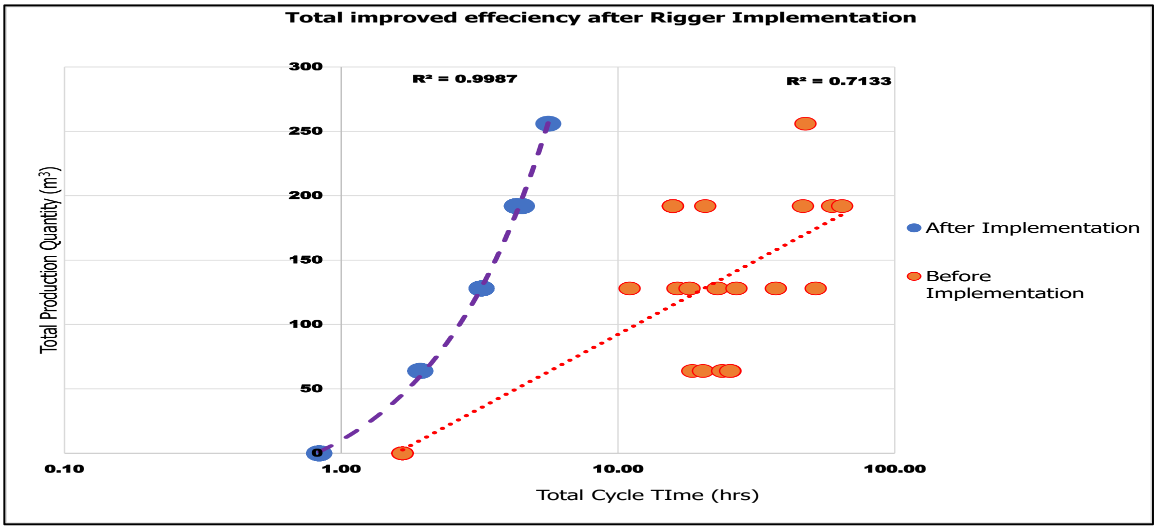

Fig 5: Haggloader efficiency before and after rigger implementation

The result shows that loading is not gradual according to the capacity of hauling. Due to loading height mucking capacity gets affected. The performance before was not remarkable due to which height improvisation has to be done. Rigger Implementation is the only possibility to enhance productivity of loading /mucking. After implementation of rigger these indices of model performance indicate an excellent correlation factor of R^2=0.9987 on the basis of observed values. The proposed model shows exceptionally high correlation factor and improvised loading capacity of Haggloader.

Major Improvements:

- The reliability in case of existing condition is poor to good
- The reliability after the implementation of Rigger is exceptional
- Loader heigh from the base of haul in increased by 3 feet
- Suitable to use for heavy dumpers having haul depth of 4 feet
- After implementation Haggloader can be employable for main tunnel
- Total hauling cost associated with the trips is reduced.

To get more intact into the topic Fig 6 gives the details of production per unit before and after the implementation of rigger.

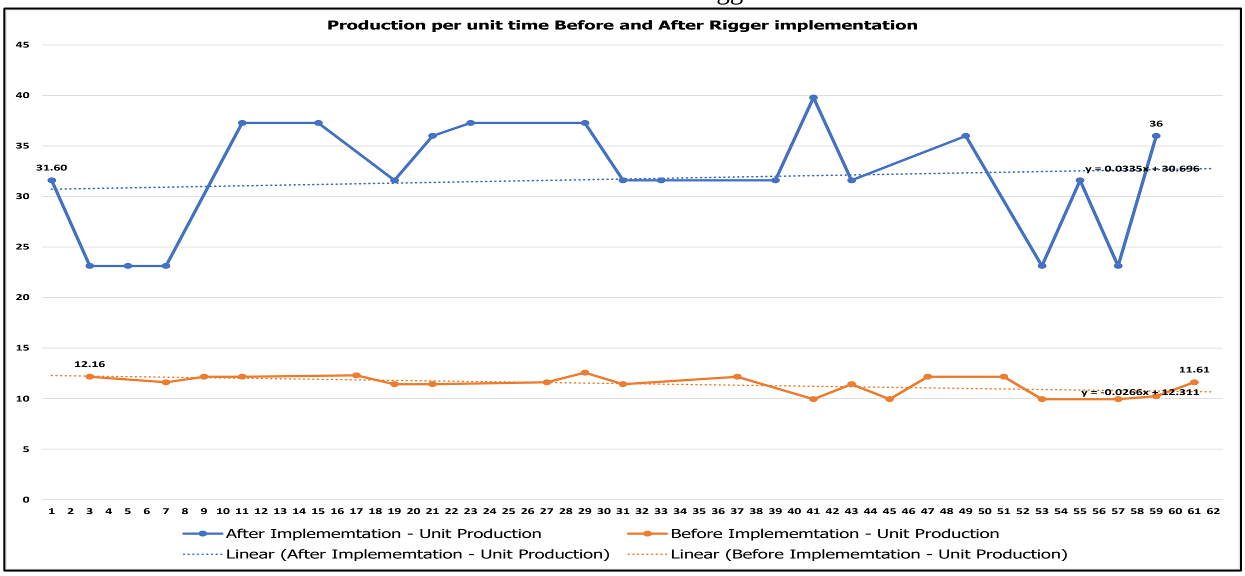

Fig 6: Unit Production

On the basis of data acquired for the two cases (before and after rigger implementation) it was found thata markedly significant increase in loading capacity was observed. As 1/3rd of the total hauling height is increased it is now suitable for heavy dumper and can be worked in main tunnel face. On the basis of mucking cycle, we have considered moving average of all the components including all types of delays, loading time, moving time or idling time of Haggloader. As it is evident from Fig 6 production per unit is plotted in linear trend where total production of unit is taken against the cycle time of Haggloader. Before implementation it was observed that total approachable height of loading is 1 feet where 12.63 to 12.61 m^3/h is reported as average moving output. Though to enhance the production quantity 3 feet is lifted from the base of haul which in turn increases the moving output by 31.70 to 31.90 m^3/h. Significantly 1/3rd of the total production quantity is improvised after implementation. The Haggloader with full attachments is now ready to deploy in main tunnel with improvised approachable height.

VI. CONCLUSION

A case study of rigger implementation for increasing productivity in drilling and blasting operation is reported. Rigger implementation to rear ends of Haggloader found to be the only option to lift total approachable height of conveyor and to maximize muck loading capacity. A hydraulically actuated rigger to lift 1 feet from the base of entire rear end is implemented. After implementation total 4 feet of height is improvise which improves mucking capacity. The monitoring of loader for data acquisition was done by monthly basis where total cycle time includes loading time, transition time, mobilization time, adjusting are the major parameters. Amongst the various Regression analysis with linear trend is proved to be an excellent module due to its highest coefficient of determination. The correlation has been performed by taking total production quantity with total cyclic time applicable for before and after implementation data. It was observed that before imposition correlation factor shows R^2=0.7133 is quite satisfactory but not in terms of hauling. The data does not seem to be gradual linearly. The impact of Rigger implementation gives highest correlation factor i.e., R^2=0.9987. To get more intact into the topic a production per unit time graph has also been plotted to give a trend of production over hauling time. Rigger implementation has proven to be an innovative change in case of reducing mucking time by maximizing the loading capacity. It improves mucking capacity with height approach to fill desirable volume in shortest period of time. This technology reduces total trip cost associated to hauling.

DECLARATION OF CONFLICT OF INTEREST

The authors declared that there is no conflict of interest in this publication.

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