International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.2, Issue No.10, pp : 947-952 1 Oct. 2013

Statistical Analysis of CMRI-RMR and Q-system for implementation in depillaring panels of Indian Coal Mines

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1. Abstract

For stability of any excavation proper design of support is essential [1]. A very common practice in underground is to make an estimation of rock load from the strata and its distribution over the underground mine workings is of prime importance [14,17 ,18]. In Indian coalmines, CMRI-RMR and NGI-Q Systems are mostly used for formulating design of support in rock engineering. Rock load in development galleries and junctions are usually calculated from CMRI- RMR while rock load for depillaring working (slices and goaf edges) is calculated on the basis of NGI-Q[2,3,4]. In NGI Q[5,6,7] system cumbersome study is required which is very much time taking job. The research work carried out aims to provide equations for determination of rock load for slices and goaf edges alone by CMRI RMR system in depillaring panel, by correlating the observed value and actual values. The observed values are those values, which are obtained from modified equation using CMRI-RMR and actual values are those which are obtained from 8 case studies for slices and goaf edges from NGI- Q system.

Keywords : NGI, CMRI, RMR, excavation

2. Objective

The objective of the research work carried out is to obtain an empirical correlation between rock load by CMRI RMR (during development) and that by Q system (during depillaring) in slices and goaf edges. An attempt has been made to suggest equation including rock load in gallery, calculated by rock load formula of CMRI RMR, which can be used to calculate the rock load for slices and goaf edges in depillaring panel, presently calculated in India using Q system, a time consuming one. Correlation was done with estimated and observed value to find feasibility of the developed formula for estimation of rock load in slices and goaf edges.

The eminent use of estimated rock load is the election of required support system. This is by virtue one of the critical decision in an underground project with low quality rock. Counting on a formulation that allows the instantaneous calculation of rock load in depillaring panel from rock load in development galleries taken onsite would provide a very helping tool in the decision making process, because two parameters are available providing two suggestions for the support system from the same original information. In this way, the technician in charge of analysing the type of support system has more information to rely on.

The empirical formulation resulting from this research is aimed at providing the additional correlation that professionals can use when working, especially with low and very low quality rock.

3. Study Area

The case studies incorporated in this paper is taken from different mines of Coal India Limited and Singreni Mines Ltd. The area chosen here from Coal India Limited is Mahanadi Coalfield Field and Southern Eastern Coalfield. Rest case studies are taken from Singreni Collieries Company Limited.

4. Geology of the Area

Pali mine is situated in Johilla area of SECL which comes under Johilla Coal Field of Madhya Pradesh. The coalfield is situated in Valley of Johilla River. In this field, Talchers, Barakars and beds of Raniganj age are developed. Hingir Rampur mine is situated in orient area of Mahanadi Coal Field. The coal field of this area comes under IB valley. The topography of the area is consisting of forest and hills .Singreni mines are part of Godavari valley coalfield trending in NW, SE is characterised by an undulating topography with low hillocks disposed over an area. Based on geographical and geological consideration, the Godavari valley coalfield is divided into 12 coal belts. Ramagundam coal belt is one of such belts located along the western margins of the Godavari Coalfield. The case studies of SCCL discussed in this research work is from Ramagundam Coal Belt. Mass Quality Classification (Q system) was used in classifying the roof rocks and for estimation of rock load. Rock Mass Rating (CMRI RMR) determined by CMRI geo-mechanical classification system is the summation of the ratings of 5 individual parameters.

5. Barton's Q-system [5, 6, 7] (Rock quality index, Norwegian Geotechnical Institute)

The rock quality index (Q) is evaluated as

$$Q = \frac{RQD * J_r * J_w}{J_n * J_a * SRF} \quad [1]$$

Where

RQD = rock quality designation
J_n = joint set number
J_r= joint roughness number
J_a = joint alteration number
J_w= joint water reduction number
SRF = stress reduction factor.

Based on the value of Q the rock mass can be described as ―exceptionally good‖ (Q=400 to 1000) to ―exceptionally poor‖ (Q=0.001 to 0.01). Using the Q value, the maximum unsupported span [2] of roof can be estimated by the formula:

Span (m) = 2 x ESR x $Q^{0.4}$ [2]

Where ESR is excavation support ratio (which is 3 to 5 for temporary mine workings and 1.6 for permanent workings). The rock load [3] (Proof) can be estimated from the empirical formula:

$$P_{roof}\ (t/m^2) = \frac{2.0 * F}{Jr * 5Q^{1/3}} \quad [3]$$

Where F = 1 if Jr is 9 or more or F= (Jr 0.5)/3 if Jr is less than 9.

Depending on the different values of the parameters and Q, 38 support categories have been identified.

6. CMRI-RMR Rock Mass Classification [2,3,5,6,14,15]

This rock mass classification [4] system is being used regularly by academic and research institutes.
The five parameters used in the classification system and their relative ratings are summarized below

SI No	Parameter	Max. rating
1	Layer thickness	30
2	Structural features	25
3	Rock weatherability	20
4	Strength of roof rock	15
5	Ground water seepage	10

Table no. 1 : Parameters for Rock Mass Rating

A. Laying thickness: Spacing between the bedding planes or planes of discontinuities should be measured using borehole strata scope in an e m long drill made in the roof. Alternately, all bedding planes or weak planes within the roof strata can be measured in any roof exposure like a roof fault area, shaft section or cross measure drift. Core drilling shall be attempted wherever feasible and the core log can be used to evaluate RQD and layer thickness. Average of five values should be taken and layer thickness should be expressed in cm.

B. Structural Features: Random geological mapping should be carried out and all the geological features (discontinuities like joints, faults and slips, and sedimentary features like cross bedding, sandstone channels) should be carefully recorded. The relative orientation, spacing and degree of abundance for all these features shall be noted. Their influence on gallery stability should be assessed and the structural index for each feature should be determined from the Table 1.

C. Weatherability [9]: ISRM standard slake durability test should be conducted on fresh samples from the mine to determine the susceptibility of rocks to weathering failure on contact with water or the atmospheric moisture. For this test, weigh exactly any ten irregular pieces of the sample (the total weight should be between 450- 500 g); place them in the test drum immersed in water and rotate it for 10 min at 20 rpm; dry the material retained in the drum after the test and weigh it again. Weight percentage of material remaining after test is the final slake durability index, expressed in percentage. Mean of three such first cycle values should be taken. Core may be broken to obtain the samples. 15.

D. Rock Strength [10]: Point load test is the standard index text for measuring the strength of rocks in the field. Irregular samples having ratio of 2:1 for longer axis to shorter axis can be sued for the test. The sample is kept between the pointed platens and the load is applied gently but steadily. The load at failure in kg divided by the square of the distance between the platens in cm gives the point load index (Is). The mean of the highest five values out of at least 10 sample tests should be taken. The compressive strength of the rocks can be obtained from the irregular lump point load index for Indian coal measure rocks by the relation: Co = 14 Is (in kg/cm2)

E. Ground water: A 2m long vertical borehole should be drilled in the immediate roof and the water seeping through the hole after half an hour should be collected in a measuring cylinder. The average of three values from three different holes should be taken and expressed in ml/minute.

Rock Mass Rating (RMR) is the sum of five parameter ratings. If there are more than one rock type in the roof, RMR is evaluated separately for each rock type and the combined RMR is obtained as:

$$\text{Combined RMR} = \frac{\Sigma\ (\text{RMR of each bed * bed thickness})}{\Sigma\ (\text{Thickness of each bed})} \quad [4]$$

The RMR so obtained may be adjusted if necessary to take account for some special situations in the mine like depth, stress, method of work.

Rock load in Roadways (t/m^2) = B.D.(1.7 – 0.037 CMRI RMR + 0.0002 CMRI RMR^2) [5]

Where,
CMRI RMR = Rock Mass Rating,
B = Roadway Width (m),
D = Dry Density (t/m^3)

SI No	Rock mass rating	Rock quality
1	0 – 20	Very poor
2	20 – 40	Poor
3	40 – 60	Fair
4	60 – 80	Good
5	80 – 100	Very good

Table 2: Classification of Rock Mass Rating

***NOTE**
In general, Rock Mass Rating (RMR) is used for design of supports in development galleries. However, due to limitations of its application to depillaring workings, many investigators adopted various approaches such as Q-classification of rock mass, numerical modelling etc for design of support system in depillaring workings, Sometimes, it is also required to design support in a depillaring panel having widely varying geo mining conditions with different support density.

7. Estimation of Rock Load in SLICES by CMRI-RMR (figure. 1)

Rock load in Slices is given by the equation (6) given below, correlating it with Rock load in roadways, the correlation found between them is 0.73 which is very encouraging.

Rock load in Slices (t/m^2) = 5.215 * ln (Rock load in Roadways) -0.213 [6]

8. Estimation of Rock Load in GOAF EDGES by CMRI-RMR (figure.2)

Rock load in Goaf Edges is given by the equation (7) given below, correlating it with Rock load in roadways, the correlation found between them is 0.775 which is very encouraging.

Rock load in Goaf Edges (t/m^2) = 7.358 9* ln (Rock load in Roadways) -1.282 [7]

Thus by CMRI-RMR system only, estimation of rock load is done for galleries, splits, slices and goaf edges in depillaring panels of bord and pillar mining by using the equations suggested for slices and goaf edges.

The observed values are those values, which are obtained from developed equation using CMRI-RMR and actual values are those which are obtained from 8 case studies for slices and goaf edges from NGI- Q system

Table no. 3

Case studies for Observed Values of Rock Load using Q-System for Slices

MINE NAME	SEAM	CMRI RMR	Q (SLICE)	ROCK LOAD by Q (t/m^2) (SLICE)	GALLERY WIDTH (m)	WIDTH of SLICE (m)	WIDTH of SPLIT (m)
Pali Incline, SECL	Johila Bottom	41.4	5	6.24	4	4	4
Duman Collier, SECL	Kaparti Seam	40	1.7	6.5	4.2	4.2	4.2
Hingir Rampur Colliery,MCL	IV Seam	37.8	1.3	7.6	4.2	4.2	4.2
Hingir Rampur Colliery,MCL	V Seam	37.8	1.95	6.7	4.2	4.2	4.2
Satpura II Mine, WCL	Lower Workable Seam	48.9	6.5	5.3	4	4	4
GDK 1 and 3 Incline, SCCL	II Seam	56	2.7	4.37	4.2	4	4
GDK 2 and 2A Incline, SCCL	III Seam	42	1.2	7.4	4	4	4
GDK 2 and 2A Incline, SCCL	IV Seam	58.3	3.45	4.23	4	4	4
GDK 7 Incline, SCCL	IV Seam	58.4	3.4	4.23	4	4	4.5

Table no. 4
Case studies for Observed Values of Rock Load using Q-System for Goaf Edges

MINE NAME	SEAM	CMRI RMR	Q (GOAF EDGES)	ROCK LOAD by Q (t/m^2) (GOAF EDGES)	GALLERY WIDTH (m)	WIDTH of SLICE (m)	WIDTH GOAF EDGES (m)
Pali Incline, SECL	Johila Bottom	41.4	10	7.82	4	4	4
Duman Collier, SECL	Kaparti Seam	40	0.88	9.96	4.2	4.2	4.2
Hingir Rampur Colliery,MCL	IV Seam	37.8	0.6	9.3	4.2	4.2	4.2
Hingir Rampur Colliery,MCL	V Seam	37.8	0.95	8.2	4.2	4.2	4.2
Satpura II Mine, WCL	Lower Workable Seam	48.9	3.25	5.3	4	4	4
GDK 1 and 3 Incline, SCCL	II Seam	56	0.8	5.51	4.2	4.2	4.2
GDK 2 and 2A Incline, SCCL	III Seam	42	0.6	9.3	4	4	4
GDK 2 and 2A Incline, SCCL	IV Seam	58.3	1.72	5.32	4	4	4
GDK 7 Incline, SCCL	IV Seam	58.4	1.7	5.32	4	4.5	4.5

Table no. 5
Estimation of Rock Load by Developed equation for Slices

MINE NAME	SEAM	CMRI RMR	ROCK LOAD for ROADWAYS	ROCK LOAD for SLICES by CMRI-RMR(t/m^2)	DENSITY	WIDTH of SLICE (m)	WIDTH of SPLIT (m)
Pali Incline, SECL	Johila Bottom	41.4	4	6.89	1.93	4	4
Duman Collier, SECL	Kaparti Seam	40	3.9	6.77	1.72	4.2	4.2
Hingir Rampur Colliery,MCL	IV Seam	37.8	3.94	6.82	1.6	4.2	4.2
Hingir Rampur Colliery,MCL	V Seam	37.8	4.16	7.09	1.7	4.2	4.2
Satpura II Mine, WCL	Lower Workable	48.9	2.63	4.83	1.78	4	4
	Seam						
GDK 1 and 3 Incline, SCCL	II Seam	56	2.76	5.07	2.7	4.2	4
GDK 2 and 2A Incline, SCCL	III Seam	42	3.39	6.08	1.7	4	4
GDK 2 and 2A Incline, SCCL	IV Seam	58.3	2.23	4.03	2.5	4	4
GDK 7 Incline, SCCL	IV Seam	58.4	2.7	4.96	2.5	4	4.5

Table no. 6
Estimation of Rock Load by Developed equation for Goaf Edges

MINE NAME	SEAM	CMRI RMR	ROCK LOAD for ROADWAYS	ROCK LOAD for GOAF EDGES by CMRI-RMR(t/m^2)	DENSITY	WIDTH of SLICE (m)	WIDTH of SPLIT (m)
Pali Incline, SECL	Johila Bottom	41.4	4	8.91	1.93	4	4
Duman Collier, SECL	Kaparti Seam	40	3.9	8.73	1.72	4.2	4.2
Hingir Rampur Colliery,MCL	IV Seam	37.8	3.94	8.8	1.6	4.2	4.2
Hingir Rampur Colliery,MCL	V Seam	37.8	4.16	9.2	1.7	4.2	4.2
Satpura II Mine, WCL	Lower Workable	48.9	2.63	5.83	1.78	4	4
	Seam						
GDK 1 and 3 Incline, SCCL	II Seam	56	2.76	6.19	2.7	4.2	4.2
GDK 2 and 2A Incline, SCCL	III Seam	42	3.39	7.7	1.7	4	4
GDK 2 and 2A Incline, SCCL	IV Seam	58.3	2.23	4.62	2.5	4	4
GDK 7 Incline, SCCL	IV Seam	58.4	2.7	6.02	2.5	4	4.5

Figure 1.
Correlation between Observed Rock load in Roadways and Rock load for Slices by Q-system

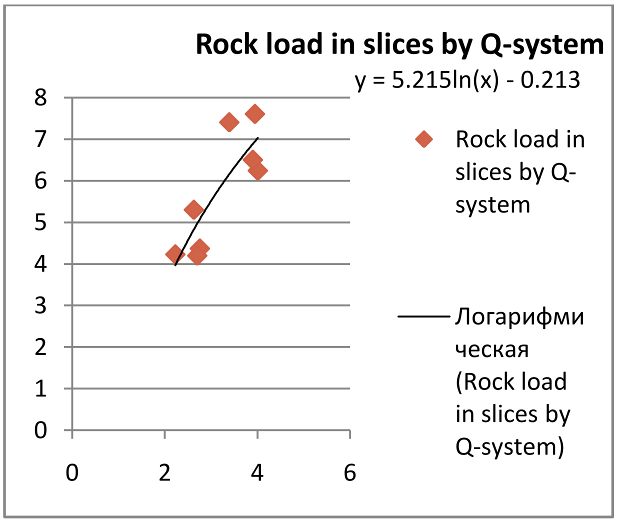


Table no. 7
Estimation of Rock Load by Developed equation for Slices

MINE NAME	SEAM	ROCK LOAD (ROAD WAYS)	Rock load in Slices (Q-System)	Estimated Rock Load for Slices (by Equation derived)
Pali Incline, SECL	Johila Bottom	4	6.24	6.89
Duman Collier, SECL	Kaparti Seam	3.9	6.5	6.77
Hingir Rampur Colliery,MCL	IV Seam	3.94	7.6	6.82
Hingir Rampur Colliery,MCL	V Seam	4.16	6.7	7.09
Satpura II Mine, WCL	Lower Workable	2.63	5.3	4.83
	Seam			
GDK 1 and 3 Incline, SCCL	II Seam	2.76	4.37	5.07
GDK 2 and 2A Incline, SCCL	III Seam	3.39	7.4	6.08
GDK 2 and 2A Incline, SCCL	IV Seam	2.23	4.23	4.03
GDK 7 Incline, SCCL	IV Seam	2.7	4.23	4.96

Figure. 2

Correlation between Observed rock load for Goaf Edges and Estimated rock load for Goaf Edges

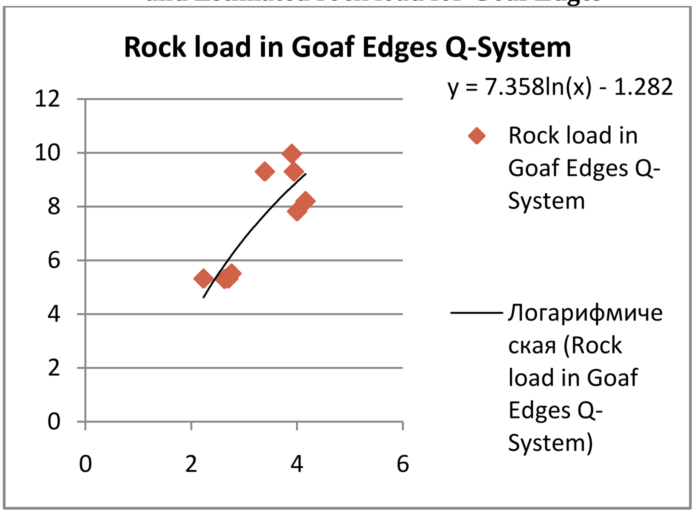


Table no. 8
Estimation of Rock Load by Developed equation for Goaf Edges

MINE NAME	SEAM	ROCK LOAD (ROAD WAYS)	Rock load in Goaf Edges (Q-System)	Estimated Rock Load for Goaf Edges (by Equation derived)
Pali Incline, SECL	Johila Bottom	4	7.82	8.91
Duman Collier, SECL	Kaparti Seam	3.9	9.96	8.73
Hingir Rampur Colliery,MCL	IV Seam	3.94	9.3	8.8
Hingir Rampur Colliery,MCL	V Seam	4.16	8.2	9.2
Satpura II Mine, WCL	Lower Workable	2.63	5.3	5.83
	Seam			
GDK 1 and 3 Incline, SCCL	II Seam	2.76	5.51	6.19
GDK 2 and 2A Incline, SCCL	III Seam	3.39	9.3	7.7
GDK 2 and 2A Incline, SCCL	IV Seam	2.23	5.32	4.62
GDK 7 Incline, SCCL	IV Seam	2.7	5.32	6.02

Figure. 3
Correlation between estimated and observed value of Rock Load by CMRI-RMR and Q for Slices

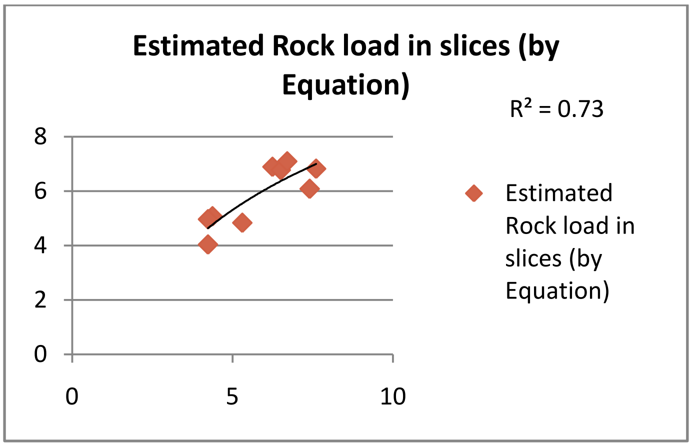
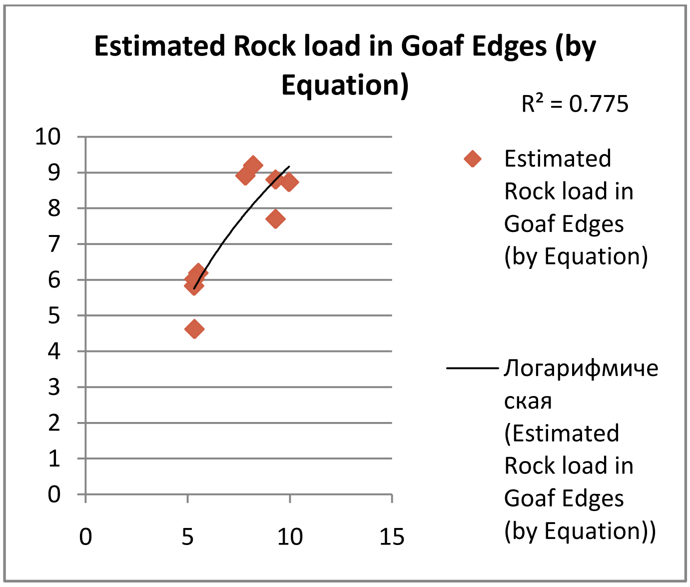


Figure.4
Correlation between estimated and observed value of Rock Load by CMRI-RMR and Q for Goaf Edges



9. Conclusion

- The equation developed for calculation of rock load in Slices and Goaf Edges, using CMRI-RMR is, Rock load in Slices (t/m^2) = 5.215 * ln (Rock load in Roadways) -0.213
  Rock load in Goaf Edges (t/m^2) = 7.358 9* ln (Rock load in Roadways) -1.282, where Rock load in Roadways = B.D.(1.7 - 0.037*CMRI RMR + 0.0002*CMRI RMR^2)

- The correlation between the observed value and estimated value of the rock load in slices and goaf edges is found to be 0.73 and 0.775 respectively, which is very encouraging, thus the above equations can be used for estimation of rock load in slices and goaf edges for depillaring panels of underground coal mines

- No cumbersome study is required which is very much time taking job in NGI Q system and hence CMRI RMR system alone can be used in depillaring panels for estimation of rock load for design purpose directly after substituting CMRI RMR value, gallery width and density of immediate roof rock

- This empirical formulation resulting will provide the additional correlation that professionals can use when working, especially with low and very low quality rock

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