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**OPTIMIZATION OF COAL PILLAR DESIGN FOR ENHANCED
EXTRACTION AND STABILITY IN BORD AND PILLAR WORKINGS: A
CASE STUDY FROM JHARIA COALFIELD, INDIA**

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Keywords	Abstract
<p><i>BORD And Pillar, Coal Pillar Stability, Factor Of Safety, CMRI Formula, Tributary Area Method, Extraction Ratio, Underground Coal Mining.</i></p>	<p>Coal pillar design is a critical component of underground mine planning in BORD and Pillar workings, directly influencing extraction ratio, operational safety, and long-term stability. In India, nearly 60% of underground coal reserves remain locked within development pillars, emphasizing the need for optimized design methodologies that balance safety and recovery. This study presents a systematic evaluation of coal pillar stability using laboratory-derived strength parameters and empirical pillar strength formulations, with special reference to a Degree-II gassy underground mine in the JHARIA Coalfield operated by Bharat Coking Coal Limited.</p> <p>Point Load Index, Brazilian Tensile Strength, and moisture content tests were conducted to estimate in-situ strength characteristics. Pillar strength was computed using the CMRI empirical formulation, while pillar stress was determined using the Tributary Area Method. Factor of Safety (FOS) was evaluated for varying gallery widths (3.0 m to 4.8 m) and pillar widths (5 m to 45 m). Results indicate that optimum pillar width ranges between 18 m and 22 m for a gallery width of 4.2 m at 266 m depth, yielding FOS between 1.3 and 1.7 with improved extraction ratio. The study proposes a correlation framework between extraction percentage and safety factor to assist mine planners in achieving higher productivity without compromising statutory safety requirements</p>



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1. INTRODUCTION

Mining is one of the earliest industrial activities and remains foundational to modern civilization. Underground coal mining in India is predominantly carried out using the Bord and Pillar method due to geological, economic, and operational considerations. Despite technological advancements, pillar design remains a complex geotechnical challenge, particularly in deeper workings.

In the Bord and Pillar system, coal is extracted in a grid-like pattern, leaving behind pillars to support the overburden. The design of these pillars must ensure:

- Stability during development
- Safety during depillaring
- Economic extraction
- Compliance with regulatory standards

An undersized pillar may result in catastrophic collapse, whereas oversized pillars reduce extraction efficiency and economic viability. Therefore, optimization of pillar geometry based on geotechnical parameters is essential

2. OBJECTIVES OF THE STUDY

The present investigation aims to:

1. Evaluate coal pillar design using laboratory-derived strength parameters.
2. Determine factor of safety (FOS) using empirical and analytical approaches.
3. Assess the influence of gallery width and pillar width on stability.
4. Identify optimum pillar dimensions ensuring safe and economic extraction.
5. Develop a correlation between extraction ratio and safety factor.

3. GEOLOGICAL AND MINE DESCRIPTION

The study area lies in the southern part of the Jharia Coalfield in Jharkhand, India. The mine is operated under Bharat Coking Coal Limited.

3.1 Geological Setting

- Formation: Barakar Formation
- Seam: VII (B) Bottom Seam
- Depth of working: 266 m
- Seam thickness: 4 m
- Dip: 5°–10° (locally steeper in southern block)
- Degree of gassiness: Degree II
- RMR: 53.3
- Roof: Shale and coal bands
- Floor: Sandstone and hard stone

3.2 Mining Parameters

Method: Bord and Pillar (Development stage)

- Gallery width: 4.2 m
- Gallery height: 3 m



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- Pillar dimension: 40 m × 40 m (centre-to-centre)
- Production system: SDL-based

4. LABORATORY INVESTIGATIONS

4.1 Point Load Test

Failure load = 1 kN

Core diameter = 54.2 mm

$$I_{50} = \frac{P}{d^2}$$

$I_{50} = 0.340 \text{ N/mm}^2$

$\sigma_c = 24 \times I_{50} = 8.16 \text{ MPa}$

4.2 Brazilian Tensile Strength Test

Failure load = 3 kN

$$\sigma_t = \frac{2P}{\pi dt}$$

$\sigma_t = 1.10 \text{ MPa}$

4.3 Moisture Content

Average moisture loss = 0.262%

The coal was observed to be soft and friable, indicating conservative pillar design is required.

5. PILLAR STRESS DETERMINATION

5.1 Tributary Area Method

For square pillars:

$$S_p = \gamma H \left(\frac{(w + B)^2}{w^2} \right)$$

Where:

- γ = Unit weight of overburden
- H = Depth
- w = Pillar width
- B = Gallery width

6. PILLAR STRENGTH DETERMINATION

6.1 CMRI Formula



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$$S = (0.27\sigma_c h^{-0.36}) + \left(\frac{H}{250} + 1\right) \left(\frac{w}{h} - 1\right)$$

Where:

- σ_c = UCS (MPa)
- h = Working height
- H = Depth
- w = Pillar width

7. FACTOR OF SAFETY

$$FOS = \frac{\sigma_p}{S_p}$$

7.1 Results Summary

Pillar Width (m)	Strength (MPa)	Stress (MPa) (B=4.2m)	FOS
15	9.739	10.895	0.89
18	11.803	10.115	1.16
20	13.179	9.736	1.35
22	14.555	9.431	1.54
24	15.931	9.181	1.73
30	20.059	8.642	2.32
40	26.939	8.119	3.32

8. DISCUSSION

1. FOS increases non-linearly with pillar width.
2. For gallery width 4.2 m, optimum pillar width lies between 18–22 m.
3. Current 40 m × 40 m pillars provide excessive safety (FOS > 3), reducing extraction efficiency.
4. Reducing pillar width to 22 m can significantly enhance extraction ratio while maintaining FOS ≈ 1.5–1.7.
5. Soft coal nature necessitates moisture-sensitive design consideration.

9. EXTRACTION RATIO ANALYSIS

Extraction ratio (e):

$$e = 1 - \left(\frac{w}{w + B}\right)^2$$

For:



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- $w = 40 \text{ m} \rightarrow e \approx 19\%$
- $w = 22 \text{ m} \rightarrow e \approx 29\%$
- $w = 20 \text{ m} \rightarrow e \approx 31\%$

Thus, reducing pillar size from 40 m to 22 m improves extraction by nearly 10% without compromising safety.

10.CONCLUSIONS

1. The coal seam exhibits low compressive strength (8.16 MPa) and moderate tensile strength (1.10 MPa).
2. CMRI formula provides realistic strength estimates for Indian conditions.
3. Existing 40 m pillars are over-conservative.
4. Optimum pillar width for the studied depth and gallery width is 20–22 m.
5. Extraction ratio can be improved by 8–12% while maintaining FOS between 1.5–1.8.
6. A design chart correlating FOS and extraction ratio is recommended for operational decision-making.

11.PRACTICAL IMPLICATIONS

- Supports DGMS-compliant pillar optimization.
- Assists mine planners in maximizing recovery.
- Enhances safety during depillaring.
- Reduces resource locking in Indian underground mines.

12.FUTURE SCOPE

- Numerical modelling using FLAC3D/Phase2.
- Long-term creep behaviour study.
- Field instrumentation validation.

Application to multiple seams across Indian coalfields

13.AUTHOR(S) CONTRIBUTION

The writers affirm that they have no connections to, or engagement with, any group or body that provides financial or non-financial assistance for the topics or resources covered in this manuscript.

14.CONFLICTS OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

15.PLAGIARISM POLICY

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