The Impact of Abutment Pressure on Gateroad Stability in Longwall Mining Along the Strike: Case Study of The Cam Pha Region, Vietnam and Future Research Directions

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Abstract

Cam Pha coal region (Quang Ninh – Vietnam) is the primary coal production area of Vietnam National Coal – Mineral Industries Group (VINACOMIN). During the 2020–2024 period, the ratio of repaired (re-supported) roadway meters to the total newly excavated roadway meters in underground mines in this region was 26.0–30.2%. This high ratio disrupts production, increases costs, and reduces mining efficiency. Currently, gateroad support designs are primarily based on the natural equilibrium arch theory (e.g. M.M. Protodyaconov, P.M. Tsimbarevich). These theories only consider the physico-mechanical characteristics of the rock mass surrounding the roadway and do not account for the longwall abutment pressure. This leads to a discrepancy between designed and actual loads, resulting in roadway deformation and failure. Based on a review of global methods for determining abutment pressure and comparing them with practical conditions in Cam Pha, this paper identifies a research gap regarding a research gap regarding the lack of a quantified model for the distribution and influence range of abutment pressure suitable for the region's specific geological conditions. The paper proposes a research direction that closely combines analytical theory, numerical simulation, and field monitoring to determine the impact of longwall abutment pressure on gateroads, aiming to optimize roadway stability solutions to mitigate abutment pressure in accordance with the geological and technical characteristics of Cam Pha – Quang Ninh coal mines.

Keywords: *underground coal mine, abutment pressure, gateroad, roadway stability, Longwall mining methods along the seam strike direction*

1. Introduction

Cam Pha – Quang Ninh region is the coal production center of Vietnam National Coal – Mineral Industries Group (VINACOMIN), with underground coal mines such as Khe Cham III, Khe Cham II-IV, Mong Duong, Thong Nhat, Duong Huy and Quang Hanh. During the 2020–2024, the underground coal output of this region reached 52.6 million tons of raw coal, accounting for 40.6% of VINACOMIN's total output. Longwall mining along the seam strike is the dominant method, contributing to 82.8% of production and 94.6% of industrial reserves. Regarding roadway support, U-steel arch support (SVP profile) accounts for 71.4%, rock bolting accounts for 8.1%, and timber support accounts for 7.7% [24].

Production experience in Cam Pha over many years shows that gateroads frequently suffer from deformation and crushing, leading to a high annual rate of re-supported roadways (increasing from 26% in 2021 to an estimated 30.2% in 2024) [24]. This situation not only results in significant financial losses and material waste but also adversely affects the overall productivity and safety of mine.

The cause of this issue stems from inadequacies in the methodology for support design. The load calculation methods currently applied are mainly based on the natural equilibrium arch theory of M.M. Protodyaconov and P.M. Tsimbarevich. This theory was originally developed for isolated roadways under static stress conditions and only considers the physico-mechanical characteristics of the surrounding rock mass. However, the coal extraction process creates large voids,, which results in the roof strata losing their natural support. According to the laws of mechanics, the weight of this rock mass redistributes and compresses onto adjacent unmined areas, including the longwall face and gateroads. This process creates zones of extreme stress concentration known as abutment pressure. Current methods for calculating loads on gateroads do not account for the impact of longwall abutment pressure, which has an intensity many times greater than static loads and is dynamic in nature. Field surveys at Khe Cham III mine[19] indicated that the actual pressure acting on the roadway is approximately three times higher than the results calculated by traditional methods. Consequently, the support structure is insufficient to bear the load, leading to deformation phenomena such as roof falls, floor heave, and rib spalling when the longwall face approaches. In complex geological-mining conditions, this can lead to "mining bumps" or coal bursts, disrupting production and directly threatening workers' safety.

In this context, this paper aims to: review global research experience regarding methods for determining the range and intensity of longwall abutment pressure and analyze the status of research on the impact of abutment pressure on gateroads in Cam Pha. Ideally, this will identify research gaps in Vietnam and propose research directions to thoroughly solve the roadway stability problem, in contribution to the improved efficiency and safety in the underground coal mining industry.

2. Global review on the impact of abutment pressure on gateroad stability in longwall mining along the strike

2.1. Factors affecting gateroad stability

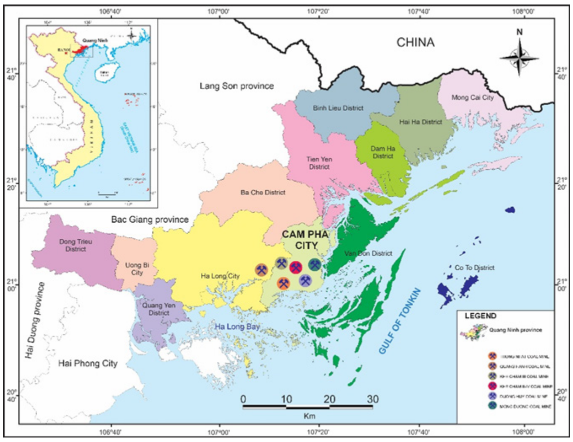


Fig. 1. Cam Pha Coal Region (Quang Ninh – Vietnam)
Rys. 1. Region węglowy Cam Pha (Quang Ninh – Wietnam)

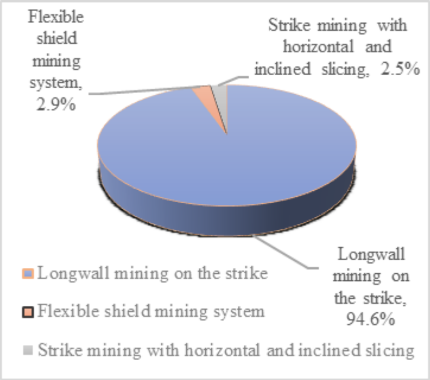


Fig. 2. Summary of industrial reserves by mining method in Cam Pha region
Rys. 2. Podsumowanie zasobów przemysłowych według metody wydobycia w regionie Cam Pha

In longwall mining systems along the strike, gateroad stability is a complex problem influenced by a combination of interacting factors. These factors can be classified into three main groups:

- Geological and Natural Conditions: Mining depth is one of the most significant factors. According to V.N. Tyupin [18] as mining depth increases, the primary stress (static load) of the rock mass increases. The rock mass accumulates high elastic strain energy, increasing the risk of sudden instability when subjected to dynamic impacts from activities such as blasting or drilling. Furthermore, the mechanical properties of the surrounding rock directly affect roadway stability, as they both transmit pressure and govern the roadway space integrity. Weak rock masses with many fractures, thin bedding, or high friability may slide or collapse even with insignificant stress increases. Additionally, rocks such as claystone and siltstone, if containing swelling minerals, will increase the volume when exposed to moisture, creating significant additional load on the support structure. Particularly in gateroads within thick coal seams, the combination of low-strength coal and low-strength roof/floor rocks (like claystone, siltstone) that are prone to delamination increases the pressure on the support system and roadway instability.
- Mine Technical Parameters: The thickness and dip angle of the coal seam are the basis for designing the longwall space and directly affect the range and intensity of the abutment pressure zone. In their study [7], Ang Li et al. found that increasing the width and height of the longwall face linearly increases the failure zones, plastic zones, elastic zones, and the scale of abutment pressure. Furthermore, the size of the chain pillar (protection pillar) affects load distribution and absorption. Improper pillar design is a direct cause of instability.
- Technology and Operational Factors: The face advance rate (fast or slow) affects the duration the rock mass is subjected to dynamic loading, impacting the development of the plastic failure zone. Additionally, the type of support (SVP-steel, bolts, etc.), density, and load-bearing capacity of the support system are factors resisting the load. A support system with insufficient bearing capacity will fail when abutment pressure acts upon it.

2.2. Mechanism of gateroad failure under abutment pressure

Roadway failure occurs when the intensity of the abutment pressure exceeds the resistance of the protective coal pillar and the support system. Extreme compressive pressure causes plastic failure, crushing the coal in the protective pillar and the surrounding roof and floor strata. This manifests externally as roadway deformation phenomena: crushing of support frames, rib convergence (spalling), and floor heave,

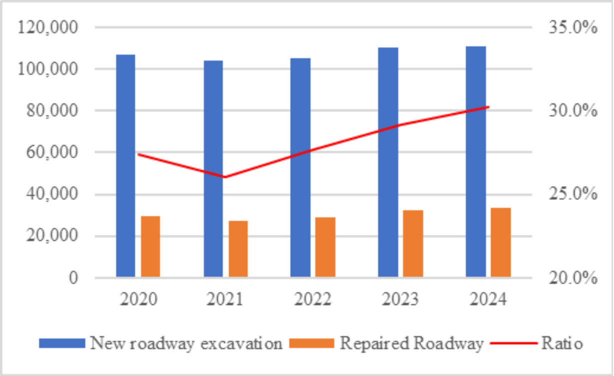


Fig. 3. Correlation chart between newly excavated roadways and re-supported roadways (2020–2024)

Rys. 3. Wykres korelacji pomiędzy nowo wykopanymi i ponownie podpartymi drogami (2020–2024)

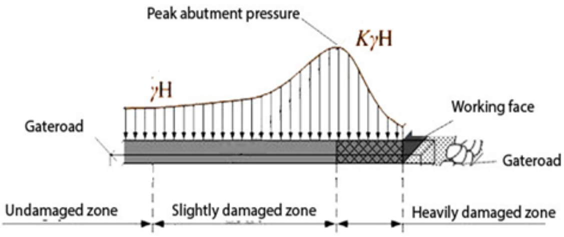


Fig. 4. Distribution of abutment pressure in front of the longwall face

Rys. 4. Rozkład ciśnienia w przyczółku przed ścianą wydobywczą

ultimately causing the roadway to lose its functionality.

The failure of gateroads in strike longwall mining primarily stems from the formation and action of a "dynamic pressure arch" during mining. Initially, when the gateroad is newly excavated, pressure is relatively stable, so the support system (U-steel, bolts) operates effectively. However, when the longwall face begins extraction, the appearance of voids disrupts the primary stress equilibrium, triggering the movement of the overlying rock mass and forming an abutment pressure arch. Studies agree that the distribution of front abutment pressure can be described as shown in Figure 4 [12, 18, 21]. Based on stress distribution, the coal seam in front of the face can be divided into three zones: the stress relief zone, the stress concentration zone, and the primary stress zone. Parallel to the longwall face, side abutment pressure forms and is distributed asymmetrically Figure 5). On the longwall face side, it is divided into a severe failure zone and a slightly fractured zone. The front abutment pressure begins to increase in the severe failure zone, nears its peak, and remains there in the mild failure zone. On the other side (solid coal side), it is divided into a heavily fractured zone, a slightly fractured zone, and an un-failed zone, similar to the stress zoning in front of the face [14]. o achieves a new equilibrium state, the rock mass above the goaf shifts and collapses. This process forms a dynamic pressure arch. This arch transmits the entire vertical load (the weight of the rock mass inside the arch) as concentrated thrust forces to the two arch footings and moves with the advance of the longwall face (Figure 6). Therefore, instead of bearing primary pressure, the gateroad must withstand the additional abutment pressure of the longwall face, which has high intensity and dynamic characteristics, leading to deformation or destruction. Manifestations of gateroads under the influence of abutment pressure include support deformation (twisting, clamp failure, leg yielding, pushing inward), reduction of usable cross-section, and floor heave (Figure 7). Therefore, determining the range and intensity of abutment pressure will assist in designing more effective gateroad support solutions.

2.3. Global research experience on abutment pressure

Methodologies for determining longwall abutment pressure on development roadways involve various approaches:

- The first approach utilizes empirical calculation formulas based on extensive years of field monitoring and measurement of rock mass displacement and deformation in the roadway vicinity during longwall mining, such as ALPS/ARMPS (USA) and ALTS (Australia). In the United States, the National Institute for Occupational Safety and Health (NIOSH) and the United States Bureau of Mines (USBM) developed the ALPS (Analysis of Longwall Pillar Stability) and ARMPS (Analysis of Retreat Mining Pillar Stability) systems [16, 25]. These methods primarily focus on the design of pillar systems for roadway protection and the determination of abutment pressure. Within these systems, the abutment angle (β) is utilized to calculate the total abutment load transferred from the gob area to the pillar system.

Based on data analysis from various mines in the United States, the abutment angle (β) is 21 for mining depths (H) less than 900 ft (274 m). For greater depths $\beta=21\times(H/900)^{-1,59}$ (where 900 <H<2050 ft). The extent of abutment pressure influence (D) is determined based on depth (H) [13, 16, 25]: (ft). The distribution of abutment pressure (σ_a) within range (D) is determined $\sigma_a(x)=\frac{3L_s}{D^3}(D-x)^2$ using L_s (Total side abut-

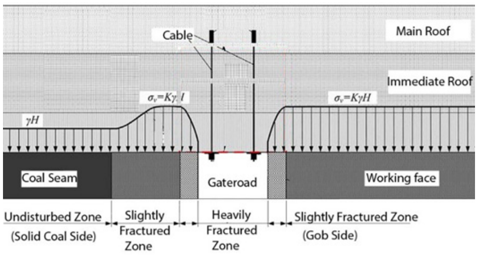


Fig. 5. Impact of abutment pressure on gateroad
Rys. 5. Wpływ nacisku przyczółka na drogę przejazdową

Fig. 7. Manifestations of gateroads under abutment pressure: a. Reduced cross-section, b. Broken column heat, c. Floor heave
Rys. 7. Przejawy dróg bramowych pod ciśnieniem przyczółków: a. Zmniejszony przekrój poprzeczny, b. Złamany słup, c. Wypiętrzenie stropu

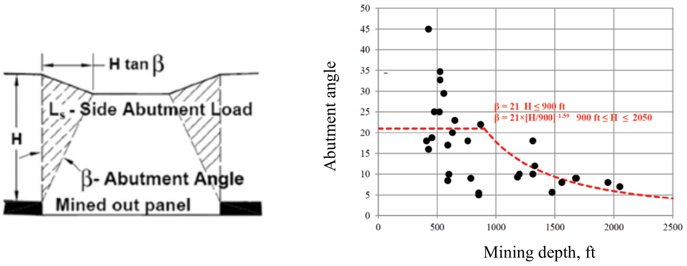
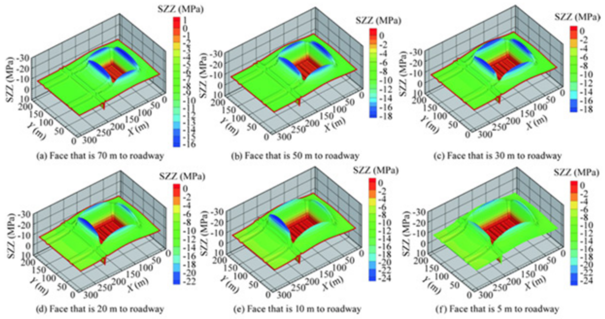


Fig. 8. Abutment angle (β) in ALPS/ARMPS system [16, 17]
Rys. 8. Kąt oporowy (β) w systemie ALPS/ARMPS [16, 17]

ment load, L_s = H×tan(β)) and x (distance from the longwall face).

In Australia, abutment angle values are adjusted for local conditions [3]: $\beta = 21{,}62 - 0{,}0221H + 0{,}0725W - 6{,}23C$ (degrees), where H is depth (m), W is pillar width (m), and C is a coefficient dependent on face aperture. Total side abutment load is $L_s = H^2\times(\tan\beta)\times\gamma$. Range of abutment pressure influence $D=5{,}13\sqrt{H}$ (m).

- The second group employs numerical simulation software such as FLAC3D, Phase2, and UDEC to model and determine stress concentration states and deformation zones within the rock mass surrounding the roadway. The fundamental principle of numerical modeling involves discretizing the rock mass (a continuum) into a mesh comprising numerous finite elements and solving mathematical equilibrium equations for each element. Consequently, these models can simulate complex behaviors such as non-linear deformation, failure, and interactions between different rock strata. Commonly applied numerical methods in mining include the Finite Difference Method (FDM), the Finite Element Method (FEM), and the Discrete Element Method (DEM). The utilization of advanced software for simulating and determining rock pressure has been widely adopted globally since the beginning of the 21st century, yielding significant results. Research [22] utilized FLAC3D software to determine abutment pressure under conditions of a 4.6 m thick seam at a depth of approximately 1000 m at the Kongzhuang Mine (Anhui, China). The simulation identified a peak abutment pressure ahead of the face of approximately 69.5 MPa (Stress Concentration Factor of 2.6) located 7 m from the longwall face. The range of significant influence was 41 m, while the total range of influence extended up to 200 m.. At the Cuijiazhai Mine (China) at a depth of 320 m, numerical simulations indicated that the range of front abutment pressure influence was 40–45 m, with a maximum abutment pressure intensity of 25.75 MPa occurring at a distance of 10 m from the longwall face[8]. Numerical simulation using Phase2 software for the D-2 roadway at the Zofiówka Mine, Poland (1000 m depth) indicated that the influence of the longwall face began at a distance of 100 m and was most intense between 40–80 m. Notably, horizontal stress (35–40 MPa) significantly dominated vertical stress (24.5 MPa), causing substantial deformation in the roadway [9].
- Another common method involves analytical-empirical models (Russia, Poland) or mechanical models (China) is widely applied in underground coal mines globally due to several advantages: simplicity, ease of application, determination of pressure values via analytical calculations, and the utilization of formulas and lookup tables that facilitate the design process.



(a) Face that is 70 m to roadway (b) Face that is 50 m to roadway (c) Face that is 30 m to roadway
(d) Face that is 20 m to roadway (e) Face that is 10 m to roadway (f) Face that is 5 m to roadway

Fig. 9. Longwall abutment pressure distribution model using FLAC3D [8]
Rys. 9. Model rozkładu nacisku na przyczółek ścianowy z wykorzystaniem FLAC3D [8]

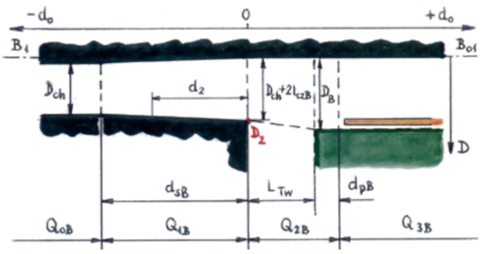


Fig. 10. Scheme for determining the range of abutment pressure influence ahead of the longwall face [1]
Rys. 10. Schemat wyznaczania zasięgu oddziaływania ciśnienia przyczółkowego przed przodkiem ścianowym [1]

In Russia, the VNIMI Institute's displacement-based rock pressure calculation method addresses the extent of deformation and displacement of the rock mass surrounding the roadway, which induces loads on support structures. This method considers factors such as the structural and physico-mechanical properties of the rock mass, seam thickness, dip angle, seam occurrence, and the influence of abutment pressure during longwall extraction [26]. The method for determining the range and magnitude of abutment pressure does not directly calculate stress values; instead, it quantifies them through the degree of rock displacement caused by the abutment pressure. According to this method, the range of abutment pressure influence varies from 30 to 150 m, with a zone of intense impact ranging from 20 to 45 m, depending on the mining depth and roof rock conditions. Additionally, the KuzNIUI Institute proposed a method to determine the range of longwall abutment pressure influence utilizing two parameters: the Reinforced Support Zone (L_c) and the Rock Pressure acting on supports at the longwall-gateroad junction [23]. Accordingly, the reinforced support zone in the gateroad is determined as $L_C=r+r_1$ (m) where: r – is the length of the gateroad ahead of the longwall face affected by mining operations (m) (m); r_1 – is the width of the longwall face in the area adjacent to the junction (m).

In Poland, Budryk's pressure wave theory (1952) represents a significant contribution to the Polish mining industry. Budryk described the stress redistribution within the rock mass by modeling the roof strata as a beam on an elastic foundation (comprising the coal seam and the floor). The extraction process induces roof deflection, generating a wave-shaped pressure curve acting on the coal seam, which peaks at the longwall face (typically 3 to 6 times the initial pressure) and gradually decreases deep into the solid coal until returning to the primitive stress state. The magnitude of this abutment pressure is directly proportional to the mining depth and the strength of the roof rock, while being inversely proportional to the wave length. According to this theory, the range of abutment pressure influence is approximately 20–40 m [2]. More recently, Alfred Biliński (2005) [1] proposed a method for determining the range of abutment pressure influence (dsB) (Figure 9) based on the relationship between rock strength (R_{z0})and abutment pressure intensity (q).

$$d_{sB}=\frac{-1}{\frac{0,02.R_{z0}}{q}+0,02}$$

The zone of most intense abutment pressure influence is characterized by the location of the inflection point on the roof subsidence curve (D_2), at a distance d_2 relative to the longwall face. When $d_2 < 0$, this point is located ahead of the longwall face. The distance d_2 is determined by the formula:

$$d_2=\frac{1}{\frac{0,025.q.n_2^{0,5}}{R_z}+0,0215}-32$$

Where: q – Longwall abutment pressure (MPa); R_z: Coal seam strength (MPa); n_2: Coefficient of rock mass displacement intensification (for a gateroad adjacent to solid coal, $n_2 = 1$)

According to this method, in Poland, the range of abutment pressure influence typically varies between 30–50 m, while the zone of maximum influence is located within the 0–10 m range.

In China, the research on abutment pressure has advanced significantly through the development of complex analytical mechanical models. These models investigate the physical mechanism of the interaction between the roof strata and the coal seam, rather than relying solely on purely empirical formulas. There are three primary mechanical models: the Limit Equilibrium Model, the Elastoplastic-Rheological Model, and the Pressure Arch Model. The Limit Equilibrium Model is established based on limit equilibrium theory, assuming coal behaves as an ideal elastoplastic material. According to this

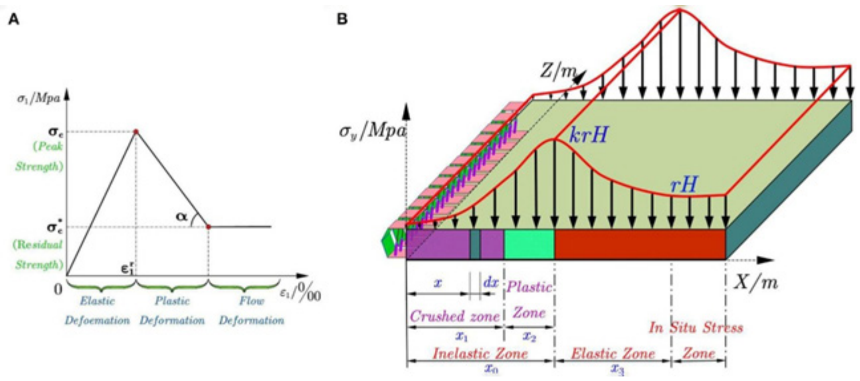


Fig. 11. Elastic-plastic strain-softening model and abutment pressure distributions [7]: (A) Elastic-plastic strain-softening model, (B) Distribution law of advances bearing pressure on the working face

Rys. 11. Model odkształcania sprężysto-plastycznego i rozkłady nacisku na filarze [7]: (A) Model odkształcania sprężysto-plastycznego, (B) Prawo rozkładu nacisku na powierzchnię roboczą

model, the influence zone ahead of the longwall face is divided into two distinct stress state regions: the plastic deformation zone (x_o) and the elastic deformation zone (x_1). This extent is determined via the friction coefficient at the interfaces (f), the internal friction angle of coal (φ), shear strength (To), coal seam thickness (M), stress concentration factor (K), unit weight of the roof strata (γ), mining depth (H), and the lateral pressure coefficient (β).

$$x = x_o + x_1 = \frac{M}{2f}\left(\frac{1+\sin\varphi}{1-\sin\varphi}\right)\ln\left(\frac{K\gamma H}{\tau_o}\times\frac{1-\sin\varphi}{1+\sin\varphi}\right)+\frac{M\beta}{2f}\ln(K)$$

At x_o, the maximum abutment pressure is defined as $\sigma_\gamma = K\gamma H$

The Elastoplastic-Rheological Model divides the influence zone ahead of the face into two primary regions (Figure 11): the inelastic zone (x_o) — comprising the crushed zone and the plastic zone — and the elastic zone (x_3).The extent of these zones depends on a combination of rock mechanical parameters and mining conditions, including: The deformation angle (θ) resulting from roof subsidence; The residual strength (σ_c*) of coal after failure; The uniaxial compressive strength (σ_c); The internal friction angle of coal (φ); The coal seam thickness (H_1); The cohesion between the coal seam and the roof, floor strata (C_1); The pressure coefficient (k_p); The friction coefficient between the coal and the roof or floor (f_1).

$$x_o = \frac{H_1}{\theta}\left\{\left[\left(K\times\gamma\times H+\frac{C_1}{f_1}-\sigma_c+\sigma_c^*\right)\times\left(\frac{f_1}{C_1+f_1\times\sigma_c^*}\right)\right]^{\frac{\theta}{2\times k_p\times f_1}}-1\right\} \text{ and } x_3 = \frac{H_1}{\beta\times f_1}\ln K$$

The abutment pressure distribution is determined as follows:

$$\sigma_{yo} = \left(\frac{C}{f_1}+\sigma_c^*\right)\left(\frac{\theta\times x}{h_2}+1\right)^{\frac{2k_p f_1}{\theta}} + \sigma_c - \sigma_c^* - \frac{M_o\times\theta}{H_1}(x_o-x)-\frac{C_1}{f_1}$$

and

$$\sigma_{y3} = K\times\gamma\times H\times e^{\frac{\beta f_1}{Hx_3}(x_0\text{-}x)(2x_3+x_0\text{-}x)}$$

In contrast to the two aforementioned models, the Pressure Arch Model focuses on the properties of the coal seam and the structure of the roof strata. This theory posits that the strata overlying the working face form a load-bearing arch structure. The extent of abutment pressure influence (L_c) is established based on the geometric parameters of the pressure arch subjected to non-linear loading and is determined as follows:

$$L_c = \frac{M}{2\tan\varphi_o}\times\frac{1-\sin\varphi_o}{1+\sin\varphi_o}\times\ln\left(\frac{1-\sin\varphi_o}{1+\sin\varphi_o}\times\frac{K\gamma H\times\tan\varphi_o}{c_o}\right)+\frac{L\times h\times\left(L-2+2B-2B^{-1}\right)+L\times H\times\left(2B^{-1}-2B\right)}{8H\left[1+\ln(K)-K\right]}$$

Where: M – Coal seam thickness (m); c_o – Cohesion of coal (MPa); φ_o – Internal friction angle of coal (radians); K - Stress concentration factor; H – Mining depth (m); γ – Unit weight of rock (kN/m³); L, h – Span and maximum height of the pressure arch (m).

The maximum abutment pressure value is reached when x = 0, at which point:

$$\sigma_y = \gamma HK^{\frac{S_p}{S_e}+1}$$

3. Current Status of Research and Application in Underground Coal Mines in Cam Pha - Quang Ninh Region

For many years, the calculation and development of support designs for gateroads in strike longwall mining systems in the Cam Pha region specifically, and within VINACOMIN in general, have primarily relied on the natural equilibrium arch theory of M.M. Protodyakonov and P.M. Tsimbarevich. This theory was originally developed for independent development roadways unaffected by mining operations, thereby neglecting the existence of longwall abutment pressure – the primary and dynamic source of loading that induces roadway instability. Consequently, supports designed via this method are intended only to resist minor static loads. They are incapable of withstanding the superimposed abutment pressure, resulting in severe failure and deformation during mining operations.

Currently, the determination of the range and intensity of longwall abutment pressure relies on empirical formulas or guidelines established through the synthesis of field data and theoretical analysis. In 2024, VINACOMIN issued new guidelines titled [15] „Guidelines for the calculation and selection of rational support structures for roadways constructed under complex geological conditions and high rock pressure in VINACOMIN underground coal mines", which introduced a method to determine the influence of longwall abutment pressure on gateroads in strike longwall mining systems based on the displacement of the surrounding rock mass.

In conjunction with analytical methods, numerical simulation utilizing software such as FLAC2D/3D has emerged

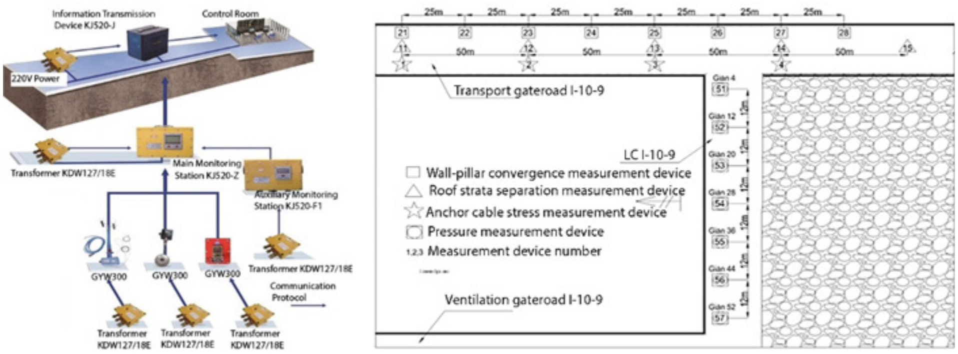


Fig. 12. The KJ520 monitoring system at longwall panel I-10-9, Khe Cham I area (Khe Cham II-IV Mine) [11]

Rys. 12. System monitoringu KJ520 w polu ścianowym I-10-9, obszar Khe Cham I (kopalnia Khe Cham II-IV) [11]

as a powerful instrument for analyzing and predicting rock pressure issues. Research conducted by Dr. Dao Viet Doan [4] at the Khe Cham Mine employed FLAC3D to perform stress-strain analysis, subsequently proposing a pillar dimensions of 3–6 meters, depending on the type of support employed. More recently, study [10] provided a detailed simulation of the evolution of the stress state within coal pillars when reducing their width in Seam 11 of the Khe Cham I Mine. The study meticulously simulated the vertical stress distribution patterns within the pillar as its width was reduced from 80 m to 5 m. The results indicated that with a wide pillar, the stress profile exhibits a double-arch shape (bimodal distribution). When the pillar is narrowed to 15 m, the two stress peaks coalesce into a single-arch profile, accompanied by a drastic increase in peak value. However, when the pillar becomes excessively narrow (less than 10 m), the maximum stress drops abruptly due to the pillar undergoing extensive plastic failure and losing its load-bearing capacity.

Furthermore, field monitoring methods provide empirical data to validate theoretical models and assess the effectiveness of implemented solutions. Roadway convergence measurements have been utilized to determine the extent of abutment pressure influence. For instance, at the T-N5-2 longwall panel (Mong Duong Coal Company), this influence range extends up to 40 m, with the most intense impact occurring within the 10–15 m zone adjacent to the working face [20]. Notably, the KJ520 real-time automatic monitoring system has been deployed on a trial basis at the Khe Cham I Mine [11].

This system facilitates the continuous monitoring of parameters such as longwall pressure, bolt load, and roof bed separation. Monitoring results from the trial of pillarless mining technology indicate that the cable bolt load peaked at approximately 34.6 tons as the working face approached and stabilized at 30 tons after the face passage. Simultaneously, the roof strata tended to restabilize at a distal approached ending the longwall face.

4. Discussion and research orientations

Although VINACOMIN issued guidelines in 2024 for support design calculations that account for rock pressure effects [15],, their practical application in the Cam Pha region remains in the initial stages. The primary cause lies in a quantitative data gap: a comprehensive set of characteristic parameters regarding the range and intensity of abutment pressure, tailored to the region's complex geological conditions, has not yet been established. Due to the absence of these precise input parameters, mines are compelled to rely on outdated assumptions or excessive empirical safety factors. This leads to a paradox: support structures result in material waste yet still suffer from localized deformation, as the load-bearing capacity is not correctly allocated to the zones experiencing peak abutment pressure.

The absence of a comprehensive methodology for determining gateroad loads that fully accounts for longwall abutment pressure and aligns with the specific geo-technical conditions of the Cam Pha region highlights a critical research gap. This gap must be bridged to establish a scientific basis for the optimization of support structures and the effective implementation of active pressure control technologies.

Drawing upon global research experience regarding abutment pressure, and to address the specific challenges to Cam Pha – Quang Ninh region, this paper proposes the following key research directions:

Developing a site-specific method for abutment pressure determination in the Cam Pha region: The research aims to establish a method for determining abutment pressure tailored to the specific conditions of the Cam Pha region, intended to refine and complement the currently applied methods. The research methodology involves integration of analytical methods, numerical modeling, and empirical field monitoring. The research workflow encompasses the synthesis of monitoring data regarding rock pressure and roadway deformation within the region. This data will be utilized in statistical analyses and numerical simulations, combined with analytical theories, to determine the evolution laws of abutment pressure and to quantify its magnitude and influence range during longwall extraction. The anticipated outcomes are sets of formulas or empirical charts for abutment pressure determination that demonstrate high reliability, are practical for implementation, and align with the production realities of mines in the Cam Pha region.

Research on the optimization of technological solutions for abutment pressure control: This study proposes a scientific framework aimed at optimizing technological solutions for controlling abutment pressure acting on gateroads within strike longwall mining systems in the Cam Pha region. The process initiates with the utilization of numerical models to conduct parametric analyses, aiming to delineate the suitable scope of application for each specific technology. Based on the simulation results, optimal solutions are proposed and implemented via field trials, integrated with monitoring to validate and comprehensively evaluate their techno-economic effectiveness.

5. Conclusion

From the comprehensive review and analysis of the current status, a number of conclusions are given by the paper that the inadequacy of current roadway support design methods, which rely principally on static pressure theory while neglecting the dynamic loading induced by longwall abutment pressure, the primary cause of the high rate of re-supported roadway (26.0–30.2%). In the context of the global transition towards utilizing rock mechanics models integrated with real-time monitoring and numerical simulation, the challenge of gateroad stability in strike longwall mining systems within Cam Pha underground coal mines requires resolution through two strategic research directions: ((1) establishing a comprehensive database and developing empirical formulas to determine abutment pressure distribution laws specific to Cam Pha geological conditions; and (2) optimizing support structures and applying active pressure reduction solutions based on these quantified parameters.

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Wpływ ciśnienia przyczółka na stabilność drogi przekopowej w górnictwie ścianowym wzdłuż wyrobiska: studium przypadku regionu Cam Pha w Wietnamie i przyszłe kierunki badań

Region węglowy Cam Pha (Quang Ninh – Wietnam) jest głównym obszarem wydobycia węgla w ramach Wietnamskiej Narodowej Grupy Przemysłu Węglowo-Mineralnego (VINACOMIN). W latach 2020–2024 stosunek metrów naprawionych (ponownie podpartych) chodników do całkowitej liczby metrów nowo wydrążonych chodników w kopalniach podziemnych w tym regionie wynosił 26,0–30,2%. Ten wysoki stosunek zakłóca produkcję, zwiększa koszty i obniża wydajność wydobycia. Obecnie projekty obudów chodników opierają się głównie na teorii łuku równowagi naturalnej (np. M.M. Protodyaconov, P.M. Tsimbarevich). Teorie te uwzględniają jedynie fizyko-mechaniczne właściwości masywu skalnego otaczającego chodnik i nie uwzględniają nacisku na przyczółek ściany. Prowadzi to do rozbieżności między obciążeniami projektowanymi a rzeczywistymi, co skutkuje deformacją i awarią chodnika. W niniejszym artykule, na podstawie przeglądu globalnych metod określania nacisku na przyczółek i porównania ich z warunkami praktycznymi w kopalni Cam Pha, zidentyfikowano lukę badawczą dotyczącą braku skwantyfikowanego modelu rozkładu i zakresu wpływu nacisku na przyczółek, odpowiedniego dla specyficznych warunków geologicznych regionu. W artykule zaproponowano kierunek badań, który ściśle łączy teorię analityczną, symulację numeryczną i monitoring terenowy w celu określenia wpływu nacisku na przyczółek ścianowych na chodniki przyścianowe, dążąc do optymalizacji rozwiązań w zakresie stabilności wyrobisk chodnikowych w celu zmniejszenia nacisku na przyczółek, zgodnie z geologicznymi i technicznymi charakterystykami kopalń węgla Cam Pha – Quang Ninh.

Słowa kluczowe: *podziemna kopalnia węgla, nacisk przyczółka, chodnik, stabilność chodnika, metody eksploatacji ścianowej wzdłuż kierunku wyrobiska*