**Journal of Computing and Electronic Information Management**
ISSN: 2413-1660 | Vol. 14, No. 1, 2024

# Application of Low-Temperature Temporary Plugging Agents in Coalbed Methane Volume Fracturing

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**Abstract:** Currently, unconventional oil and gas fields employ volume fracturing technology, and temporary plugging and diversion techniques have become one of the main methods for increasing production. The Mixi coalbed methane block in Yibing has a formation vertical depth of 800-1000 meters and a relatively low average formation temperature of 30 degrees Celsius. The temporary plugging agents currently in use face challenges during reservoir stimulation, including difficulty in withstanding pressure differentials, poor degradability, and significant reservoir damage, resulting in unsatisfactory implementation effects. Therefore, the water-soluble temporary plugging agent RD-1 was selected as the preferred option. Laboratory performance evaluation experiments have demonstrated that this temporary plugging agent exhibits good sealing and degradation properties. Field trials have shown good temporary plugging and diversion effects, with noticeable pressure increase during plugging and significantly improved stimulation volume. It has demonstrated good applicability in coalbed methane volume fracturing, accumulating valuable experience for efficient development of this block.

**Keywords:** Temporary blockage; Coalbed methane; Microtherm; Fracturing.

## 1. Introduction

Coalbed methane (CBM) has become one of the significant energy sources in China, with rich CBM resources found in the Mixi Block. The main coal seams in the Mixi Block are 42-43# and 45#, with depths ranging from 1000 to 1300 meters and an average formation temperature of 30°C. The coal seams are characterized by developed cleats and micro-fractures, low Young's modulus, and high Poisson's ratio. Conventional fracturing technology has resulted in low degrees of coal seam modification and consequently low gas production in this area. Temporary plugging and diverting volumetric fracturing technology can achieve larger modification volumes and higher utilization rates[1] . Due to the large scale and high displacement of volumetric fracturing, the efficacy, pressure resistance, and solubility of temporary plugging agents are critical. Moreover, the strong adsorption capacity of CBM requires that dissolved temporary plugging agents do not cause secondary damage to the formation.

Temporary plugging agents are classified into balls, particles, fibers, and powders based on their morphology, and must possess high pressure resistance, degradability, reservoir safety, and controllable plugging duration [2]. Effective plugging of temporary agents involves migration, bridging, filling, and compaction. Parameters such as perforation, particle size, and concentration significantly influence plugging speed [3]. Spherical temporary plugging agents, once seated, may have low stability due to fluid erosion [4].

Temporary plugging agents form temporary blockage bands of certain thickness and length, using particle material bridging or plate-like structures to block fractures. The heterogeneous nature of coal lithology leads to uneven fracture propagation, making the application of temporary plugging agents crucial for fracture diversion and flow redistribution. Various types of temporary plugging agents, including water-soluble, alkali-soluble, acid-soluble, starch-based degradable, and polylactic acid agents, have been developed domestically and internationally to meet fracturing and production enhancement needs.

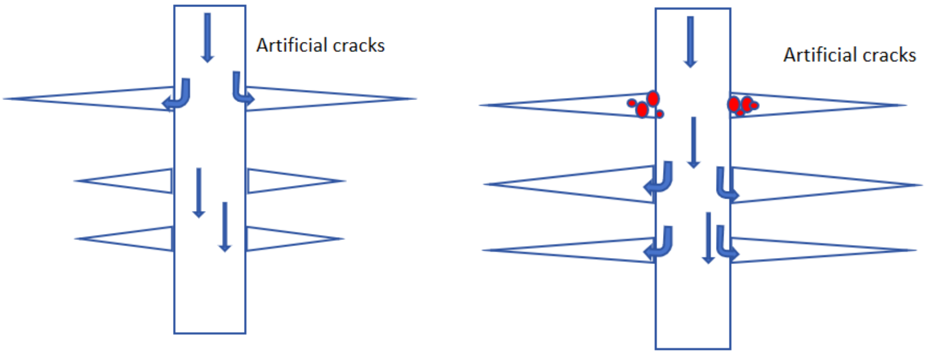
However, several challenges remain in the application of temporary plugging agents in CBM. Inadequate degradation under low-temperature conditions can leave residual agents in the formation, affecting subsequent production. The low temperatures of coal seams reduce the degradation efficiency of conventional agents, possibly resulting in residuals that impair formation permeability and gas production. Insufficient pressure resistance can lead to agent failure under low-temperature and high-pressure conditions. Additionally, degradation byproducts can potentially harm formation permeability if not fully dissolved or absorbed. Complex fracture networks in coal seams can result in uneven distribution of temporary plugging agents, leading to suboptimal plugging effectiveness and poor redirection of fractures.

To address these issues, further optimization of temporary plugging agents and techniques is necessary to enhance degradation performance, pressure resistance, and safety under low-temperature conditions, ensuring effective application in CBM extraction. The Mixi Block's small pore throats, developed joints, and low temperatures necessitate the selection of temporary plugging agents with favorable performance under low-temperature conditions.

## 2. Principle of Temporary Plugging Technology

### 2.1. Interlayer Temporary Plugging Diversion Principle

Due to the strong vertical heterogeneity and significant differences in mechanical properties of coal reservoirs, initial fracturing cannot fully modify the coal seam vertically. Temporary plugging agents can block high-flow pores temporarily (Fig.1), forcing fracturing fluid to enter low-flow pores, thereby modifying coal seam segments with larger mechanical properties and achieving uniform coal seam modification [6].




a.Before temporary plugging b. After temporary plugging

**Fig.1** Interlayer Diversion Principle

## 2.2. Particle Filling and Bridging Principle

Bridging is achieved using larger particles for primary bridging and smaller particles for filling. Based on the size of fractures and pores, temporary plugging follows the "1/2-2/3 bridging rule" and "multistage optimal filling" method. "Optimal filling" involves filling the voids between large particles with smaller particles, and further filling smaller voids with even smaller particles:

First-level particle size: $0.5D \le d_1 \le 0.67D$

Second-level particle size: $0.056D \le d_2 \le 0.12D$

Third-level particle size: $0.01D \le d_3 \le 0.035D$

# 3. Evaluation of Temporary Plugging Agents

Effective temporary plugging materials must be capable of blocking reservoirs or fractures and self-decomposing. New temporary plugging materials should be degradable, allowing them to degrade thermodynamically and kinetically within a specific timeframe without environmental pollution. Common biodegradable materials include polylactic acid (PLA), polyglycolic acid (PGA), and polybutylene adipate terephthalate (PBAT). In this study, a novel degradable biopolymer material, RD-1, synthesized from PLA, PGA, and PBAT prepolymers, was used (Fig.2). By adjusting the ratios of raw materials, RD-1 can meet degradation needs at different well temperatures [7].

**Fig.2** RD-1 Temporary Plugging Agent

## 3.1. Degradation Experiment

The Mixi Block employs active water volumetric fracturing, with KCl as a key clay stabilizer. KCl concentration varies with the gamma-ray (GR) value of the coal seam. When the natural gamma-ray value is ≤20 API, 0.5% KCl is used; for 20 API < GR ≤ 40 API, 1% KCl is used; and for 40 API < GR ≤ 80 API, 1.5% KCl is used. The degradation experiment was conducted using KCl solutions at concentrations of 0.5%, 1%, and 1.5%, with a temporary plugging agent concentration of 5%. The experimental method is as follows:

(1) Set the temperature of a constant-temperature drying oven, dry filter paper to a constant weight (m1), accurate to 0.1mg.

(2) Weigh a certain amount (m2) of temporary plugging agent (accurate to 0.1 mg) and place it in a cup with 100 ml of active water.

(3) Place the cup with the temporary plugging agent into a water bath, heat to the required temperature, then filter the sample using filter paper. Place the filter paper and sample in a 25℃ constant-temperature drying oven for 48 hours to constant weight (m3).

(4) Calculate the degradation rate (η) using the formula:

$$\eta = \frac{m_1 + m_2 - m_3}{m_2} \times 100\% \tag{1}$$

Experimental results (Fig. 3) show that the temporary plugging agent maintains a dissolution rate below 5% within the first 4 hours, ensuring effective plugging during construction. The final dissolution rate after 24 hours exceeds 99%, indicating no secondary formation damage.

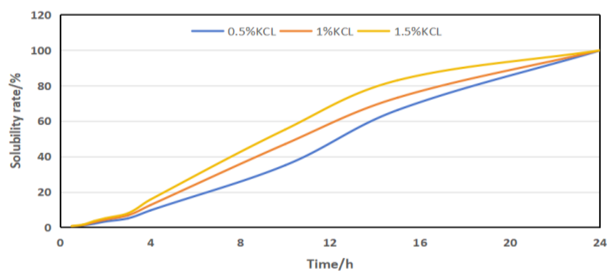



**Fig. 3** Dissolution Rate of Different KCl Concentrations

## 3.2. Pressure Resistance Experiment

To test the pressure resistance of the temporary plugging material, a laboratory pressure resistance experiment was conducted as follows:

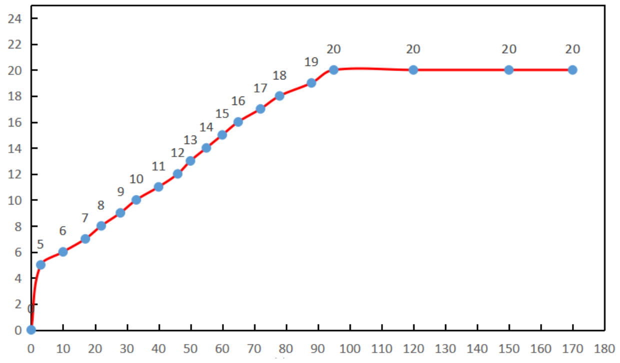


**Fig.4** Pressure Resistance Test Results

(1) Place an artificial slit steel core with a 0.5 mm slit into a core holder. Load a certain amount of granular and powdery temporary plugging agents, add a small amount of water to compact. (2) Connect the pipelines, check for leaks. If no leaks are detected, apply a confining pressure of 4-5 MPa. (3) Set the constant-temperature oven to the desired temperature, wait for 30 minutes, then start pumping. Observe the pressure change and fluid output. If the pressure stabilizes at 20 MPa for a certain period without dropping, the test is qualified.

Results (Fig.4) show that the temporary plugging agent has good pressure resistance, with a capacity of up to 20 MPa, fully meeting construction requirements.

## 3.3. Core Damage Rate Experiment

Coal samples from the Mixi CBM block were selected, prepared into coal cores, and subjected to damage testing using the temporary plugging agent solution to measure the impact on core permeability. Preparation, preservation, saturation, permeability measurement, and damage rate calculation of coal cores followed the national energy standard NB/T 10034-2016 "Evaluation Method for Water-Based Fracturing Fluid Performance in CBM Reservoirs" . Results show that the damage rate of the temporary plugging agent solution is far less than 5% across different KCl concentrations, fully meeting construction requirements.

**Table 1.** Results of Core Damage Experiments

| Serial Number | Damage Fluid Type | Initial Permeability/ ×10-3μm2 | Post-Damage Permeability/ ×10-3μm2 | Damage Rate/ % |
| --- | --- | --- | --- | --- |
| 1 | 0.5%KCL+5%Agent | 0.85 | 0.83 | 2.3 |
| 2 | 1%KCL+5%Agent | 0.94 | 0.91 | 3.1 |
| 3 | 1.5%KCL+5%Agent | 0.64 | 0.63 | 1.6 |

# 4. Field Application Results

The temporary plugging agent was applied in the Mixi Block, using 0.5% KCl active water and volumetric fracturing. The construction displacement was 16-18 $m^3$/min, using 40/70 mesh proppant for sandblasting and 30/50 mesh quartz sand as the main proppant, followed by 20/40 mesh proppant. Wells MDX1 and MDX2 employed interlayer temporary plugging with 3 mm 50 kg + 40/100 mesh 100 kg agents. The 3 mm particles bridged at the fracture mouth, while the 40/100 mesh particles filled the interior. Post-application, pressure increased by 8.55 MPa and 10.5 MPa respectively (Figs.5-6). The construction pressure post-plugging increased by 8-9 MPa and 10-12 MPa respectively, indicating successful new fracture initiation. Post-fracturing production reached 2140 $m^3$ and 2379 $m^3$ per day, significantly higher than adjacent wells, demonstrating the excellent performance of the temporary plugging agent

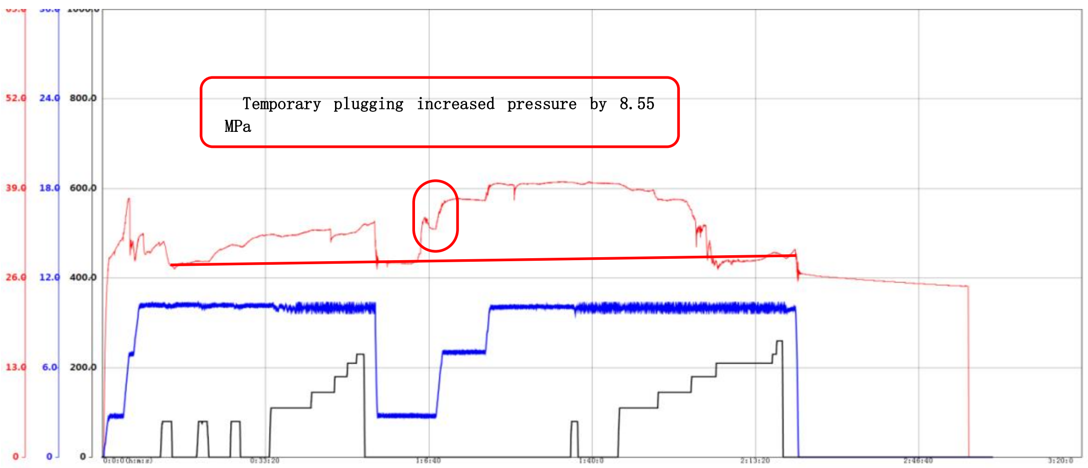



**Fig.5** Field Application Results for Well MDX1

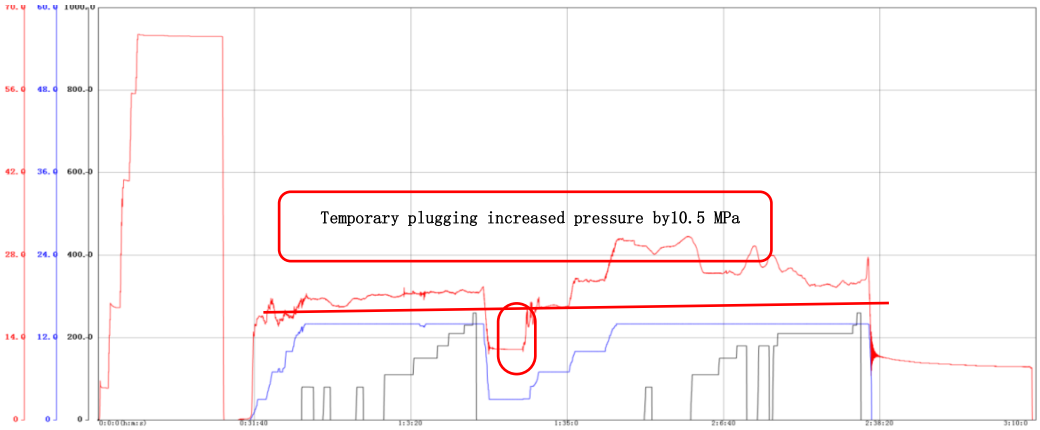



**Fig. 6** Field Application Results for Well MDX2

# 5. Conclusions

(1) Based on the geological characteristics of coalbed methane (CBM) in the Mixi Block, the use of interlayer temporary plugging and diverting volumetric fracturing technology has been effective in increasing the modification volume of coal seams. This method reduces the need for isolation tools while enhancing the control area of individual wells and increasing CBM production.

(2) Experimental optimization identified the RD-1 temporary plugging agent as suitable for low-temperature applications. The agent achieved a dissolution rate of over 99% within 24 hours, with pressure resistance exceeding 20 MPa and a core damage rate significantly less than 5%, meeting the requirements for CBM operations.

(3) Field applications demonstrated that the addition of the temporary plugging agent significantly increased construction pressure, with plugging pressures rising by 8-10 MPa. Daily gas production increased on average, achieving the expected outcomes. This temporary plugging technology is suitable for volumetric modifications in the CBM of the Mixi Block.

# References

[1] WANG Liguo, TANG Zhaoging, LI Ykui, et al. Research and application of deflection fracturing technology in coalbed methane well[J]. Coal Geology & Exploration, 2018, Vol.46 (No.2), p.8-14.

[2] ZHA0 Liqiang, CHEN Xiang,ZOU Honglan, et al. Areview of diverting agents for reservoir stimulation [J].Journal of Petroleum Science and Engineering, 2020,Vol.187,p.106734.

[3] YANG Chen, ZHOU Fujian, FENG Wei, et al. Pluggingmechanism of fibers and particulates in hydraulie fracture[J]. Journal of Petroleum Science and Engineering, 2019, Vol.176,p.396-402

[4] Lu Zhiyong.Progress and prospect study on temporary plugging agent for diverting fracturingJ. Scienee Technology and Engineering, 2020,Vol.20(No.31),p.12691-12701

[5] FAN Huabo, XUE Xiaojia,AN Jie,et al. Development and perommance evaluation of medium-low temperature degradable temporary plugging agent in tight oil horizontal wells[J]. Fault-Block 0il & Gas Field,2019, Vol.26 (No.1), p.127-130.

[6] Wang Zhihong,Ou Yangwei,et al.Multistage Bridge Temporary Plugging for Formation Protection in Hechuan Gas Reservoi [J].Jouranl Of ChongQiang University Of Science And Technology(Natural Science Edition), 2012, Vol.12 (No.05),p.77-79.

[7] XIONG Chunming, SHI Yang, ZHOU Fuian, et al.High efficiency reservoirstumulation plugging and based on temDorary diverting for deep reservoirs[J]. Petroleum Exploration & Development, 2018, Vol.45(No.5),p.888-893.