Efficiency and sustainability: Evaluating the performance of lime-based expansive agents in hard rock mining – A field study

Mekgwe M, Mmola T and Grobler H

University of Johannesburg

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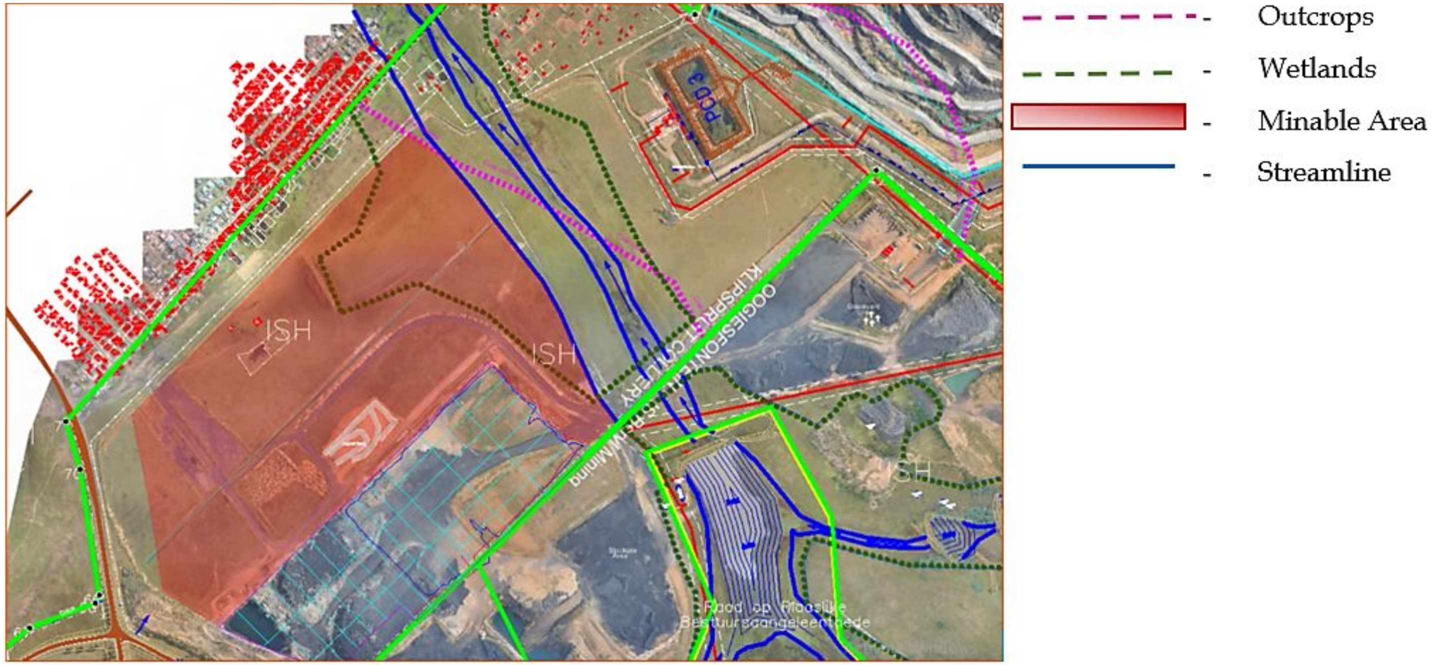
Introduction

Study Background

- Based at Mpumalanga, in Klipspruit Colliery – one of the operations owned by Seriti Resources Holdings (Pty) Ltd.



(Source: Klipspruit Colliery)

Legal Constraints

Challenge with compliance to the following acts:

- Mine Health and Safety Act 29 of 1996, Chapter 4 relating to explosives law, and
- National Environmental Management Act 107 of 1998

Legal Constraints

The MHSA (Act 29 of 1996), Chapter 4.16 paragraph 2 : “no blasting operations are carried out within a horizontal distance of 500 metres of any public building, public thoroughfare, railway line, power line; any place where people congregate or any other structure, which it may be necessary to protect in order to prevent any significant risk,” (MHSC, 2018)[1]

Aim

Evaluate the efficacy of expansive agents in hard rock-breaking for the removal of the overburden - sandstone, siltstone and shale.

Literature Review

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20 YEARS 2005-2025

Our Future. Reimagined.

Sterilisation

- Sterilisation refers, to the loss of the possibility to extract mineral resources [2] .
- Determined by mining considerations in the value chain - metallurgical [2] process, marketing, legal, environmental, social and governmental that assess the feasibility of profitable extraction [2][3].
- Sterilisation reduces resource availability, potential economic losses, adverse social implications, and job losses [4]5][6].
- Mitigation strategies are technological advances and sustainable practices.

NERB

- *Non-explosive Rock Breaking* (NERB).
- Potential solution to avoid litigation processes for non-compliance of mines near residential developments [7].
- Expansive agents are chemical NERB methods.

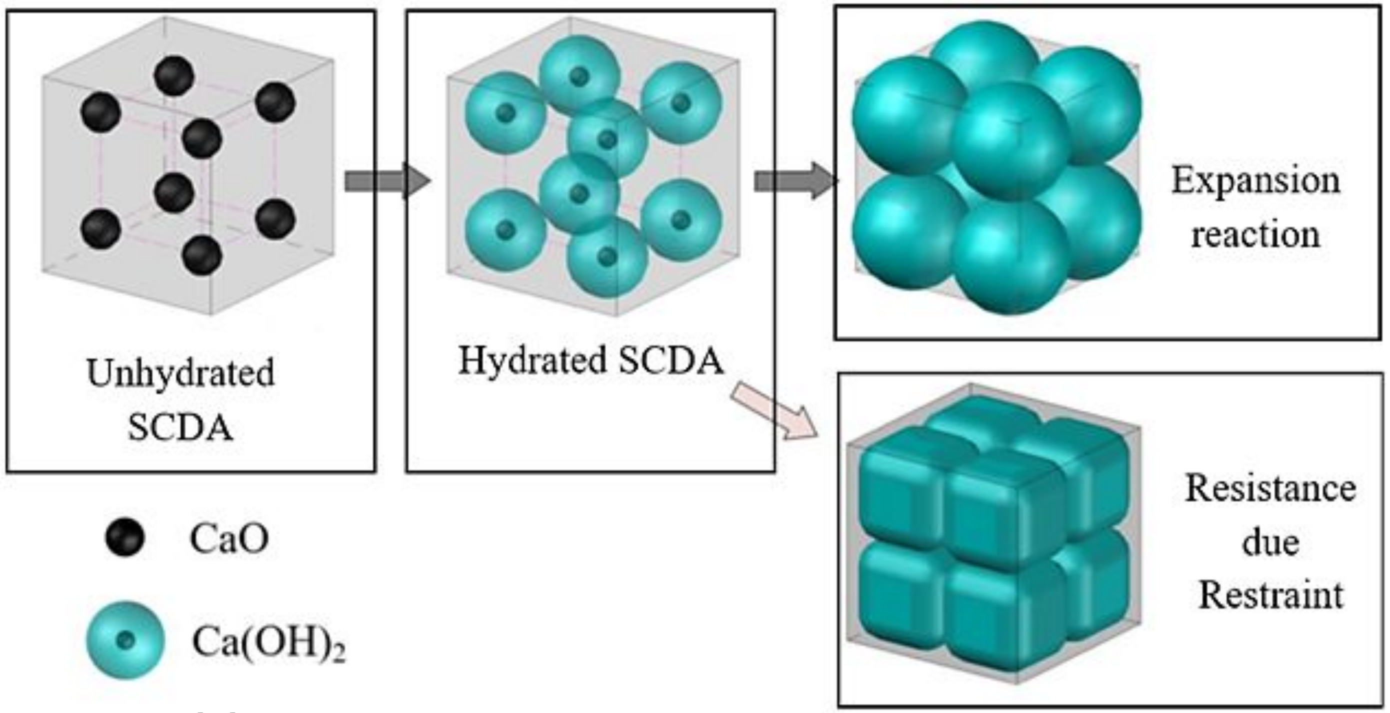
Lime-based Expansive agents

- Expansive agents are recognised with different names – soundless cracking demolition agent (SCDA), soundless cracking agents, non-explosive demolition agents, soundless stone cracking powder, static cracking agents (SCA), expansive demolition agents, non-explosive demolition agents, expansive mortar, etc.
- Primary constituent is quick-lime (CaO) [8][9].
- Type G expansive agent, according to *American Concrete Institute (ACI)* [10].
- Lime-based expansive agents - greyish, powdery lime-based chemical admixture added to cementitious material, that generates compressive stresses due to volumetric increase or swelling that induces tensile fracturing [11][8][12].

Lime-based Expansive agents

- The agents are not flammable or explosive, safety adherence is relatively high, they have low breaking power, and the cracking time is longer (usually more than 10 hours), therefore are static in mechanism [13].
- Expansion pressure = 50 – 80 MPa [14].
- Maximum expansion tine = 12-24 hours [12].

Operational Mechanism

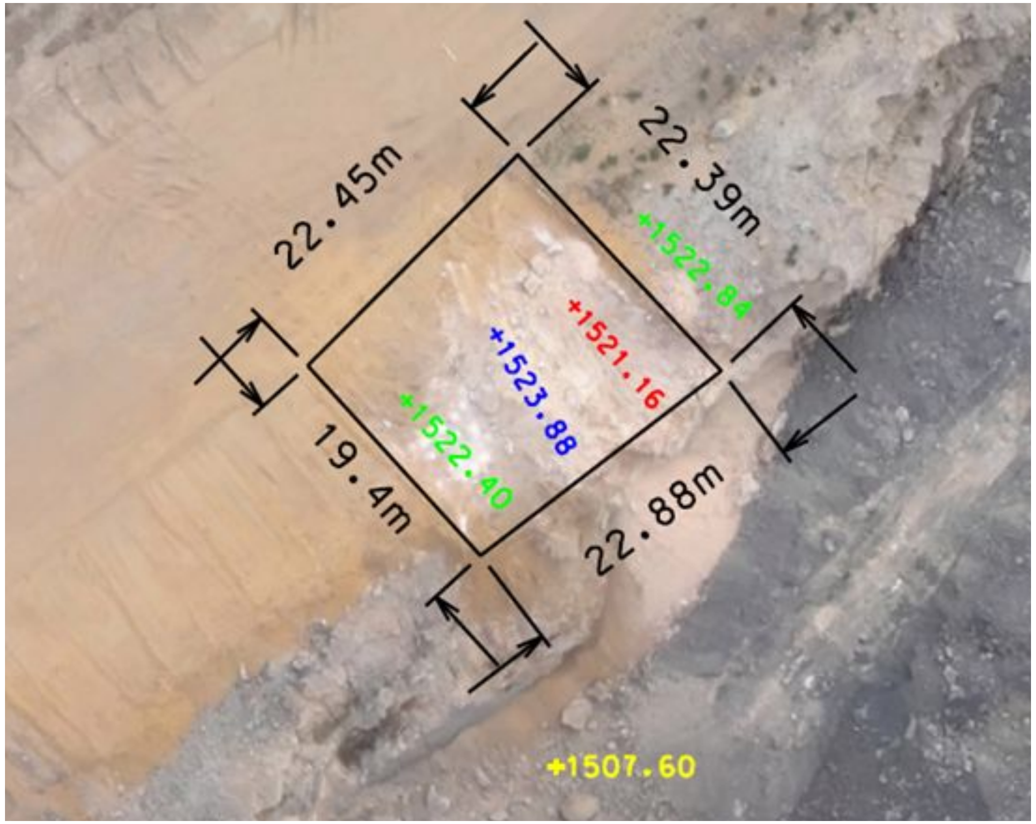


(Xu et. al., 2023)[16]

$$CaO + H_2O \rightarrow Ca(OH)_2$$

Field Study

Field Site – Portion 10



(Source: Klipspruit Colliery)

Baseline Data

Lithology	Density (g/cm^3)	UCS (Mpa)	E (Gpa)	Poisson's Ratio
Sandstone	2.47	66.33	8.89	0.25
Siltstone	2.47	137.57	20.60	0.33

Geometric Pattern Layout

Areas	Row number	Number of Holes	Spacing (m)	Burden (m)	Angle of Drill Production Hole (°)
1	1	19	B=1	B=1	10
	2	20	B=1	B=1	5
	3	20	B=1	B=1	5
2	4	9	L=1.2	L=1	~ 0
3	5	17	B=1.2	R=1.5	~ 0
2	6	16	B=1.2	B= 1	~ 0
4	7	13	B=1.5	B= 1.2	~0
	Total Holes	114			

Site Preparation

Water bowser


Berm

Equipment and Machinery

Equipment and Machinery

Results

Progressive Expansion

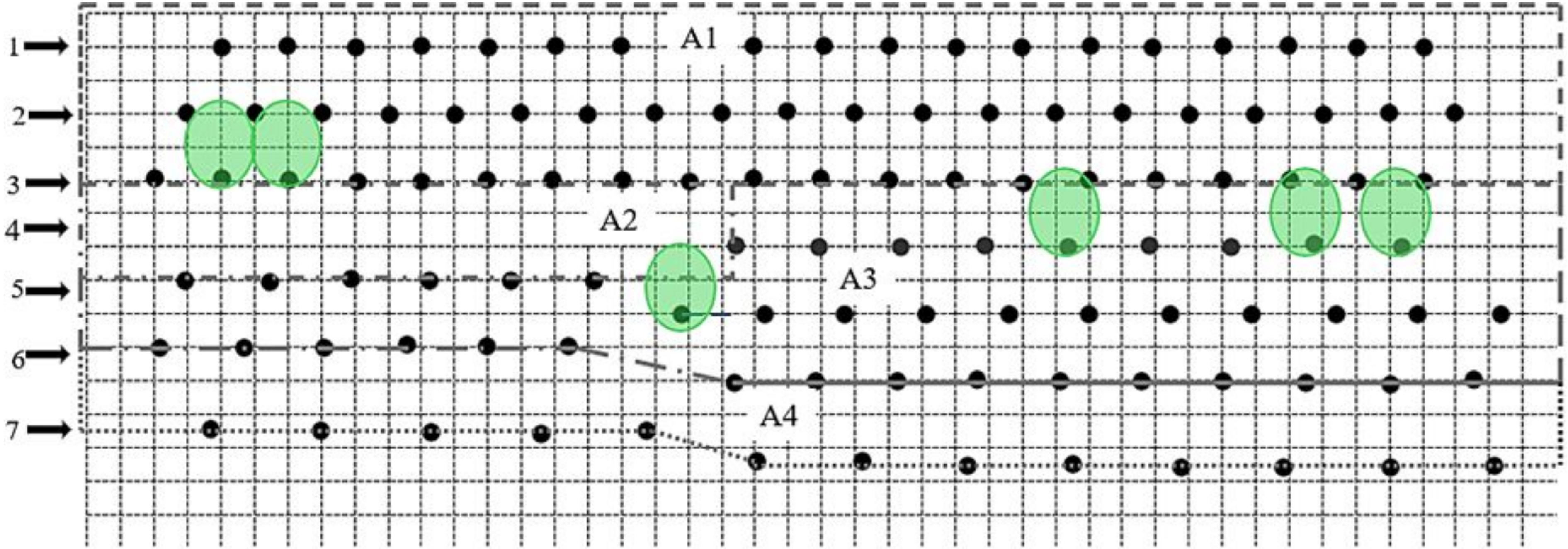
Observations

Observations of row two on day four

Longitudinal fracture in the rock mass, give visible appearance as cracks in the axial direction.

Observations

- An estimated number of six diagonal cracks were observed in the field site.
- Area 3 with the highest number of longitudinal cracks in the diagonal direction, was – H.S :1.2 m and Bx of 1 m, and S/B =1.2



Statistics

Correlation:

- **S/ Bx and number of diagonal cracks**: r = 0.3598 - higher S/ Bx ratios is associated with more diagonal cracks. It suggests that while ratio matters, burdenx and spacing individually have stronger effects on crack development.
- **Spacing and number of diagonal cracks:** r = –0.4644 – a negative correlation, therefore indicates as hole spacing increases, the number of cracks decreases.
- **Burdenx and number of diagonal cracks:** r = –0.7735 - a negative correlation, which suggests that as the burdenx increases, the number of cracks.

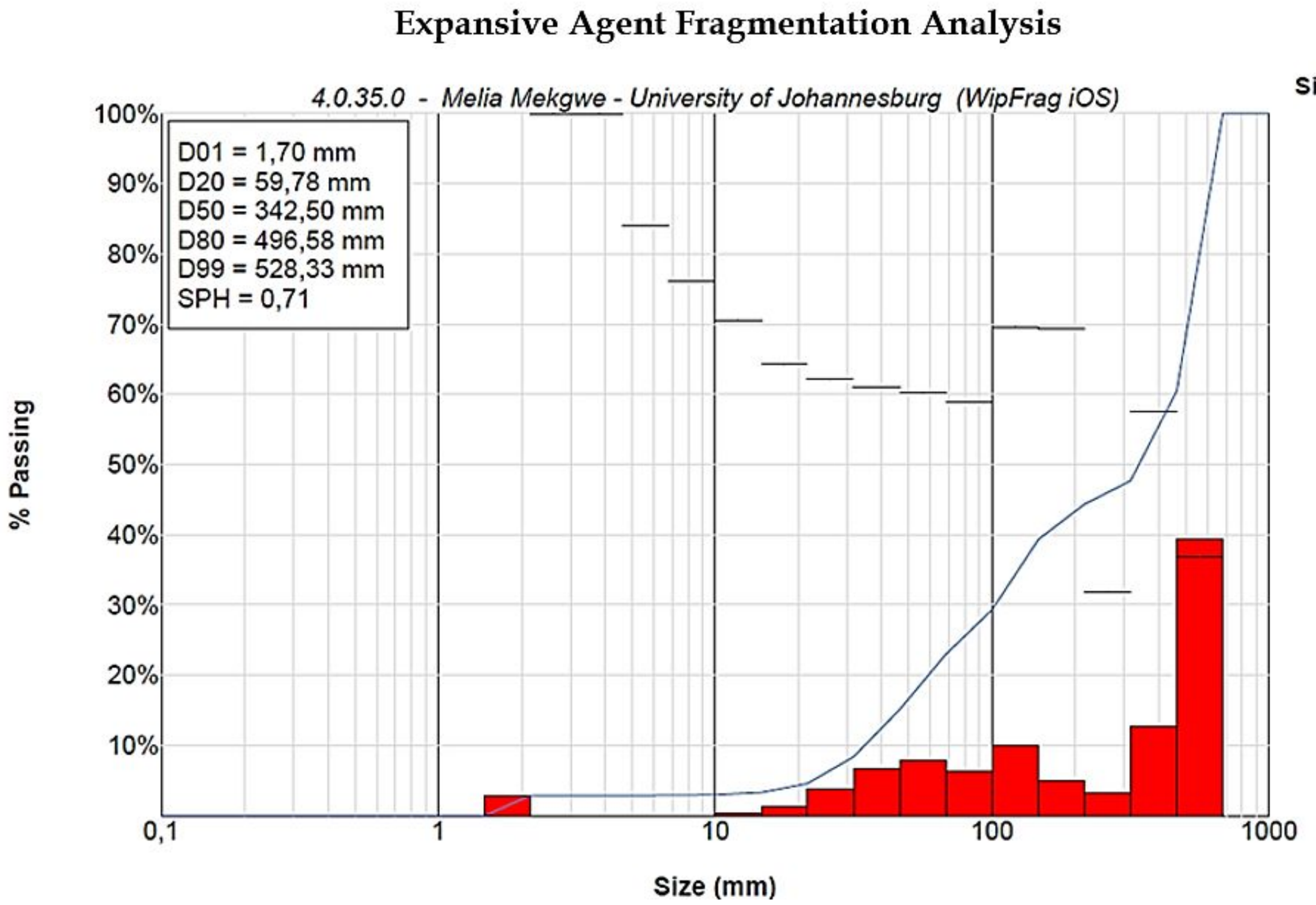
Statistics

Multi-linear Regression:

Variables	Coefficients	Standard Error	t Stat	P-value
Intercept	-16	26.77205	-0.59764	0.58227
Spacing (m)	-16.6667	23.47619	-0.70994	0.516938
$Burden_x$ (m)	13.33333	21.90515	0.608685	0.575606
S/B_x	20	27.65901	0.723092	0.509644

All probability values are above 0.05 alpha - indicating that there is no statistical significance to establish causation.

Fragmentation Analysis



Size (mm)	% Passing
1000,00	100,00%
681,00	100,00%
464,00	60,50%
316,00	47,71%
215,00	44,35%
147,00	39,37%
100,00	29,35%
68,10	23,01%
46,40	15,16%
31,60	8,40%
21,50	4,59%
14,70	3,32%
10,00	3,00%
6,81	2,93%
4,64	2,92%
3,16	2,92%
2,15	2,92%
1,47	0,00%
1,00	0,00%
0,68	0,00%
0,46	0,00%
0,32	0,00%
0,22	0,00%
0,15	0,00%
0,10	0,00%

Hole Spacing = 1m
Burden = 1m

Equipment Compatibility

- D_{50} (mean particle size of rocks) = 342.50 mm
- D_{80} (80% of the fragmentation size) = 496.58 mm

Compatible Equipment:

- Jaw Crusher = General maximum feed width of 1600 x2514 mm [17][18].

Conclusion

Future work and Conclusion

Recommended future research

- Develop best mining practices, especially investigating the effects of burden
  - Longitudinal cracks – diagonal direction

Conclusion

- Correlation exists with variables the hole spacing and burden, which influence crack propagation.
  - Increase in hole spacing decreases diagonal cracks.
  - Increase in burden decreases diagonal cracks.
  - Increase in in S/B increases diagonal cracks.
- No statical significance to establish a causal relationship.

Reference List

1. MHSC, 2018. Mine Health and Safety Act 29 of 1996 and Regulations. Mine Health Safe Council 588, 588.
2. Pendock, M.J., 1984. Sterilisation and safeguarding of mineral deposits in Britain. Minerals and the Environment 6, 23–41. https://doi.org/10.1007/BF02072662
3. Stephenson, P.R., 2000. The JORC Code–Its operation and application, in: Proceedings of the Codes Forum. pp. 81–89.
4. Lumadi, V.W., Nyasha, S., 2024. Technology and growth in the South African mining industry: An assessment of critical success factors and challenges. SAIMM 124, 163–171.
5. Sermet, E., Nieć, M., 2021. Not Mining Sterilization of Explored Mineral Resources. The Example of Native Sulfur Deposits in Poland Case History. Resources 10, 30. https://doi.org/10.3390/resources10040030
6. Wrighton, C.E., Bee, E.J., Mankelow, J.M., 2014. The development and implementation of mineral safeguarding policies at national and local levels in the United Kingdom. Resources Policy 41, 160–170. https://doi.org/https://doi.org/10.1016/j.resourpol.2014.05.006

Reference List

7. Hinze, J., Nelson, A., 1996. Enhancing Performance of Soundless Chemical Demolition Agents. J Constr Eng Manag 122, 193–195. https://doi.org/10.1061/(ASCE)0733-9364(1996)122:2(193)

8. Gagné, R., 2016. Expansive agents, in: Science and Technology of Concrete Admixtures. Elsevier, pp. 441–456. https://doi.org/10.1016/B978-0-08-100693-1.00022-9

9. Li, S., Feng, Y., Yang, J., 2021. Expansion Mechanism and Properties of Magnesium Oxide Expansive Hydraulic Cement for Engineering Applications. Advances in Materials Science and Engineering 2021, 5542072. https://doi.org/10.1155/2021/5542072

10. ACI, 2010. ACI 223R-10 Guide for the use of shrinkage compensating concrete. Farmington Hills: American Concrete Institute.

11. Hinze, J., Brown, J., 1994. Properties of soundless chemical demolition agents. J Constr Eng Manag 120, 816–827.

12. Soeda, K., Yamada, S., Nakashima, Y., Nakaya, S., Haneda, H., Izawa, N., 2023. Non-explosive demolition agent, in: Demolition Methods and Practice V1. CRC Press, pp. 116–125.

13. Zhou, H., Xie, X., Feng, Y., 2018. Rock breaking methods to replace blasting. IOP Conf Ser Mater Sci Eng 322, 022014. https://doi.org/10.1088/1757-899X/322/2/022014

Reference List

14. Sakhno, I., Sakhno, S., 2024. Directional fracturing of rock by soundless chemical demolition agents. Heliyone26068. https://doi.org/10.1016/j.heliyon.2024.e26068

15. Xu, Z., Cao, Y., Li, C., Tai, L., He, S., 2023. Mechanism of Hard Rock Static Blasting-induced Crack Expansion.

16. Gupta, A., Yan, D., 2016. Jaw Crusher, in: Gupta, A., Yan, D. (Eds.), Mineral Processing Design and Operations. Elsevier, pp. 123–152. https://doi.org/10.1016/B978-0-444-63589-1.00004-6

17. Metso, 2011. Crushing and screening handbook . Metso Expect Results .

Questions