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# Study on the mechanism of zonal disintegration around an excavation

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ABSTRACT

Zonal disintegration is a curious phenomenon and has received considerable attention recently. Using traditional static mechanics cannot well explain the phenomenon of the alternately distributed cracked zones. In this paper, the process of a slowly unloading P-wave reflecting from a free surface has been investigated and the result shows that as a slowly unloading P-wave encounters a free surface, it could cause the phenomenon of zonal disintegration. In order to confirm this result, two numerical models of defected rock around an excavation under the action of a slowly unloading P-wave are established. The slowly unloading P-wave is induced by a steel plate impacting the target rock with a proper speed, and their interaction lasts for a long time. The simulation results show that if the strength of slowly unloading P-waves is in a certain range, the phenomenon of zonal disintegration could be observed, and if the incident wave is not a slowly unloading P-wave, such as a rectangle wave, the phenomenon of zonal disintegration will not occur.



## 1. Introduction

It is well known that in underground rock engineering, excavations will induce damages around an excavation, and this damaged zone can be divided into several sub-zones, such as plastic zones and loose zones. However, many in-situ results from South Africa, Russia and China showed a curious phenomenon of zonal disintegration existing around excavations in deep mines, and this has received considerable attention recently in the field of rock mechanics and rock engineering. The zonal disintegration refers to that the distribution of cracked zones is not integrated, but layered, and the cracked layers distribute alternately with the intact layers as shown in Fig. 1.

The phenomenon of zonal disintegration was first observed in Talnakh–Oktyarb mine at the depth up to 1050 m. The test results by Adams and Jager [1] from Witwatersand gold mine in South Africa showed that generally the thickness of intact zone was about 1.0 m, and the alternately distributed zones could extend to 12 m from the working face.

In-situ experiments in Taimyrskii mine of Russia by Shemyakin et al. [2–5] showed that ‘around a tunnel, there are zones of fissured and non-fissured, propagating discretely into the depth of surrounding rock mass’. They pointed out that the thickness of the cracked layers was about 1.0–1.5 m, and the thickness of the intact layers was also about 1.0–1.5 m, and the number of cracked layers usually was more than 3 around a tunnel.

Using detector through boreholes in Huainan mine of China, Li et al. [6] observed that zonal disintegrations did exist, and they presented their measurement result of the alternately cracked layers as shown in Fig. 2. Similar results have been obtained by the in-situ velocity tests by using ultrasonic waves in Jinchuan mine of China [7] and by measuring the multipoint displacements in a Ni mine in China [8].

It is very imperative for us to clearly understand the mechanism of zonal disintegration due to its significant effect on the stability of underground engineering structures. It could be related to many underground engineering disasters, such as rockbursts and coal-gas outbursts. Unfortunately, until now, zonal disintegration is still complex for us, and the mechanism of zonal disintegration is still not clear. The traditional static mechanics theory cannot well explain the phenomenon of the alternately distributed cracked zones around excavations. Under this scenario, the best approach to the study is first to generate an extensive experimental database, and based on this database to perform a theoretical study. At the same time, it is essential to investigate the mechanism through numerical models so as to obtain a better understanding of the dominant parameters that control zonal disintegration.

Recently, many methods, such as in-situ observations, theoretical analyses, numerical simulations, and model tests, are implemented to investigate the curious phenomenon of zonal disintegration. Some researchers [9,10] investigated the mechanism of zonal disintegration through theoretical study, and tried to determine the range of zonal disintegrations. Some researchers [11,12] studied the special

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phenomenon of zonal disintegration by the numerical method. Through model tests, Gu et al. [13] studied the mechanism of layered fracture within the surrounding rock of a tunnel in a deep stratum. Pan et al. [14] employed gesso material to model a tunnel, but they failed to find zonal disintegration phenomenon. Shemyakin et al. [2–5] also conducted model tests in a laboratory to investigate the zonal disintegration phenomenon they observed in Taimyrskii mine. Sellers and Klerck [15] investigated the discontinuity effect on zonal disintegration. Zhang et al. [16] used a 3D geomechanical model to investigate zonal disintegration inside surrounding rock mass of a deep tunnel. Tan et al. [17] have explored a zonal disintegration

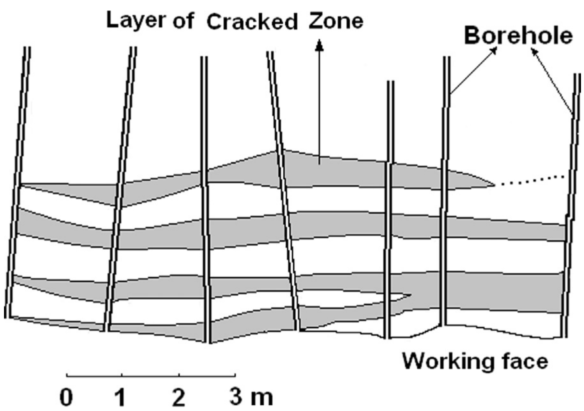


**Fig. 1.** In-situ testing results of the distribution of the cracked layers from Witwatersand gold mine of South Africa (according to [1]).

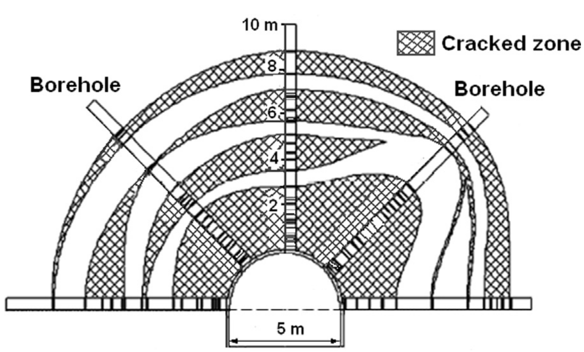


**Fig. 2.** Distribution of cracked zones in Huainan mine of China (according to [6]).

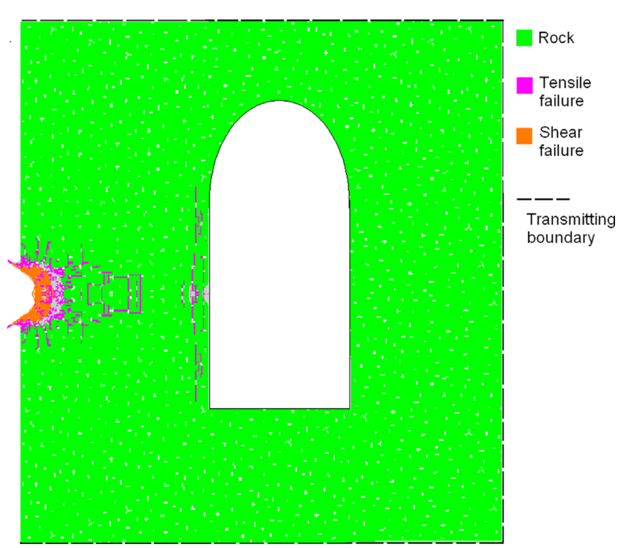


**Fig. 3.** Blasting induced spalling cracks near a tunnel surface.

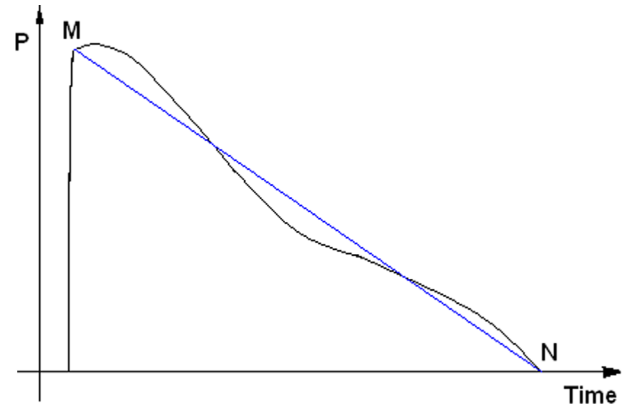


**Fig. 4.** A slowly unloading P-wave.

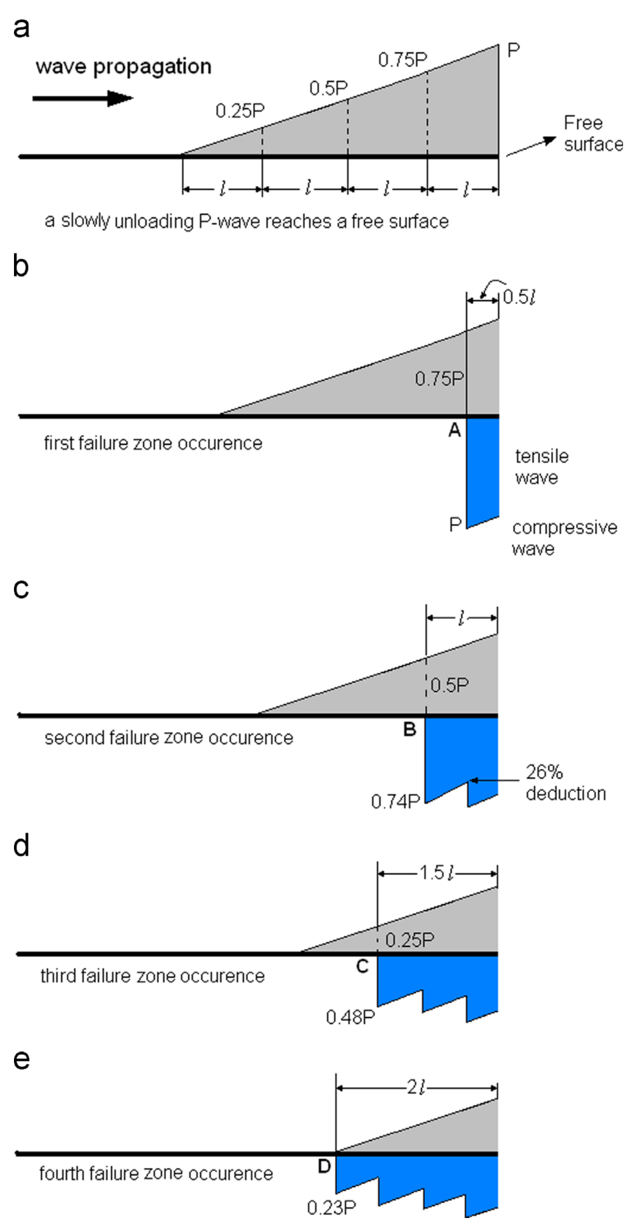


**Fig. 5.** Sketch illustrating the mechanism of zonal disintegration under a slowly unloading P-wave around a free surface; after a failure zone, the amplitude of the wave will reduce, and suppose the deduction is 26%.