Studies on Excavation Damage by Blasting in Underground Research Laboratories

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1. Introduction

For the deep geological disposal of high-level radioactive waste(HLW) in deep underground, the validation and demonstration of HLW disposal system in underground research laboratories(URL) are essential. To construct an URL in deep underground by blasting, it is inevitable to have an excavation damaged zone(EDZ) around the tunnels. In the EDZ various rock properties including permeability, elastic modulus, rock strengths, and thermal conductivity are changed. The size and characteristics of EDZ are dependent on the original rock properties, rock conditions, blasting design, depth, discontinuities, and tunnel geometry. Lots of studies for investigating the characteristics of EDZ and possible influence of EDZ in many URLs in foreign countries.

2. Excavation damaged zone

An EDZ is developed by blasting impact as well as stress redistribution after excavation. EDZ is defined as a zone that has suffered permanent irreversible changes in the rock properties, and a disturbed zone that is dominated by a change in states, such as stress and pore pressure, and the changes are insignificant or reversible(Fig.1). Table 1 lists the EDZ extents measured at different URLs. In the EDZ, various rock properties are changing from its original properties. In the case of elastic modulus, it was reduced 19~82% in the EDZ compared to its original value.

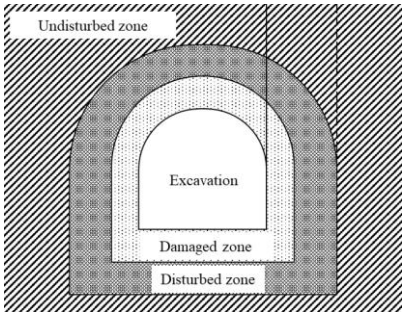

Fig. 1. EDZ around an underground tunnel.

Table 1. EDZ size in crystalline rock

Experiment site (Country)	Depth (m)	EDZ extent(m)
ASPO-access tunnel (Sweden)	80	1~1.7
ASPO-ZEDEX(Sweden)	420	0.3-0.8
ASPO-TASQ(Sweden)	450	0.3
ASPO-TASS(Sweden)	450	0.25
Stripa(Sweden)	340	~0.8
URL-Room2009(Canada)	240	0.3
URL-Mine by tunnel(Canada)	420	0.2~0.3
URL-tunnel sealing(Canada)	420	~1.0
URL-blast damage(Canada)	240	~0.6
Onkalo(Finland)	500	0.3
GTS(Switzerland)	450	~2.0
Mizunami(Japan)	500	1.0
Kamaishi mine(Japan)	250	1.0
KURT(Korea)	100	0.6~1.5

3. Prediction of excavation damaged zone

In order to investigate the possible influence of different parameters such as excavation methods, explosives, initiation system, time delay, and pre-existing fractures on the development of EDZ, studies had been carried out. Fig.2 shows the

blasting design for investigating the influence of time delay between perimeter blast holes on the fracture length developed by blasting.

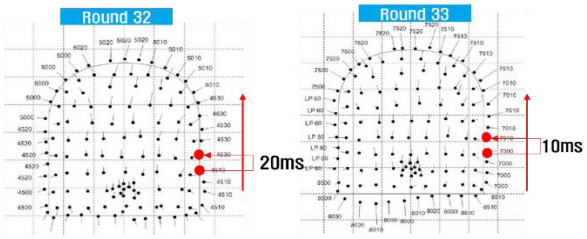

Fig. 2. Blasting to check the influence of time delay between blast holes in Sweden ASPO[1].

From the studies, it was found that mechanical excavation and controlled blasting can significantly reduce the extent of EDZ. Shorter time delay between perimeter blast holes could reduce EDZ size. Water can enhance the crack extension. For predicting the extent of EDZ, an empirical equation, Eq.1, was used in Onkalo. Fig.3 shows the predicted possible extent of fractures(R_c) from blasting[2]

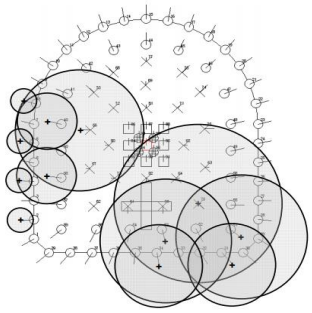

Fig. 3. Prediction of EDZ from blasting design[2].

$$R_c = R_{co} \times F_h \times F_t \times F_v \times F_b \qquad (1)$$

where, R_{co} is uncorrected crack length, F_h, F_t, F_v, F_b are factors for hole spacing, delay time, water content, and rock condition, respectively.

In this study, the ground vibration equation was used to predict the extent of EDZ(D_{EDZ}).

$$D_{EDZ} = \left(\frac{K E}{\sigma_t V_p}\right)^{\frac{1}{1.5}} \sqrt[3]{W} \qquad (2)$$

where, K is site specific constant, σ_t is tensile strength, V_p is P wave velocity, E is Young's modulus, and W amount of explosive. Fig.4 shows the comparison between the prediction using Eq.2 and the measurement at KURT.

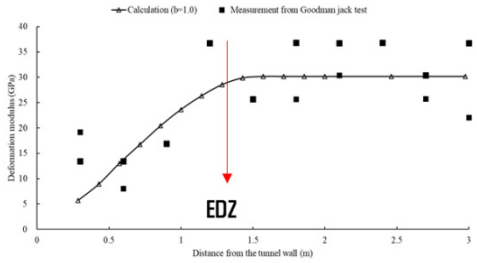

Fig. 4. Predicted EDZ using ground vibration equation.

4. Conclusion

It is inevitable to have EDZ around an underground tunnel. In this study, the studies from foreign URLs were review and derived conclusions about the influence of different parameters such as blasting method, delay time, blasting design, etc. Furthermore, a new way for predicting the extent of EDZ based on ground vibration equation was suggested.

Acknowledgement

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