EXCAVATION DAMAZED ZONE IN TUNNEL

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Abstract: **Due to shattering effect of blasting, mainly three zones are formed around the tunnel. During tunnel excavation, blast induced damage or Excavation Damage Zone (EDZ) interacts with existing geological structure of the rock-mass. This can and cause over-break and stability issues during and after excavation. Today the EDZ is determined by correlation-based methods, although direct measurement is possible. This paper throws light for, in depth exploration methods for EDZ assessment during excavation.**

The prediction of damage to the rock mass is a very important factor to evaluate the quality of the excavation process in tunnelling, so that it would allow the optimization of explosive charges utilized in successive blasting rounds, as well as lowering risks of instability from rock loosening, less support costs and water inflows. Upon developing a mathematical approach to evaluate rock damage from underground blasts, practical applications were accomplished to confirm it, both in tunnelling excavations and underground mining. Examples of these studies are described in detail.

Keywords: **Prediction, EDZ, instability, tunnelling, explosive charges, geologic- structure**

I. Introduction

The excavation damage zone (EDZ) and disturbed rock zone (DRZ) are used synonymously in early studied to describe the region of rock adjacent to an underground opening that has been significantly damaged or disturbed due to the redistribution of in-situ stresses. A redistribution of stresses and rearrangement of rock structures will occur in this zone and result in drastic changes of stress distribution, mainly through the fractures and cracks induced by excavation The creation of any underground opening creates a zone of disturbed rock around it. Within this disturbed zone there may exist a zone of damaged rock.

1.1 Excavation Influenced Zone-

The excavation-influenced zone **(EIZ)** is typically used to distinguish the outer **zone** around the opening, where reversible changes caused by stress redistribution have occurred (Lanyon, 2011; Hudson et al., 2008; Davies and Bernier, 2003).

1.2 Excavation Damage Zone-

The construction of an underground opening leads to changes in the in situ stress regime surrounding the excavation. The opening influences the rock mass due to the redistribution of the stresses and results in the disturbance of the surrounding ground. At great depths, massive to relatively slightly or moderately fracture.

During tunnel excavation, blast induced damage or Excavation Damage Zone (EDZ) interacts with existing geological structure of the rock-mass. This can and cause over-break and stability issues during and after excavation. Today the EDZ is determined by correlation-based methods, although direct measurement is possible. This paper presents investigation methods for EDZ quantification during excavation. The literature review and the case study applications are summarized in a comprehensive table with benefits and limitations of the different investigation methods. The EDZ can be reduced by adjusting the blasting plan, specific charge as well as improving the quality of the drill and blasting procedures.

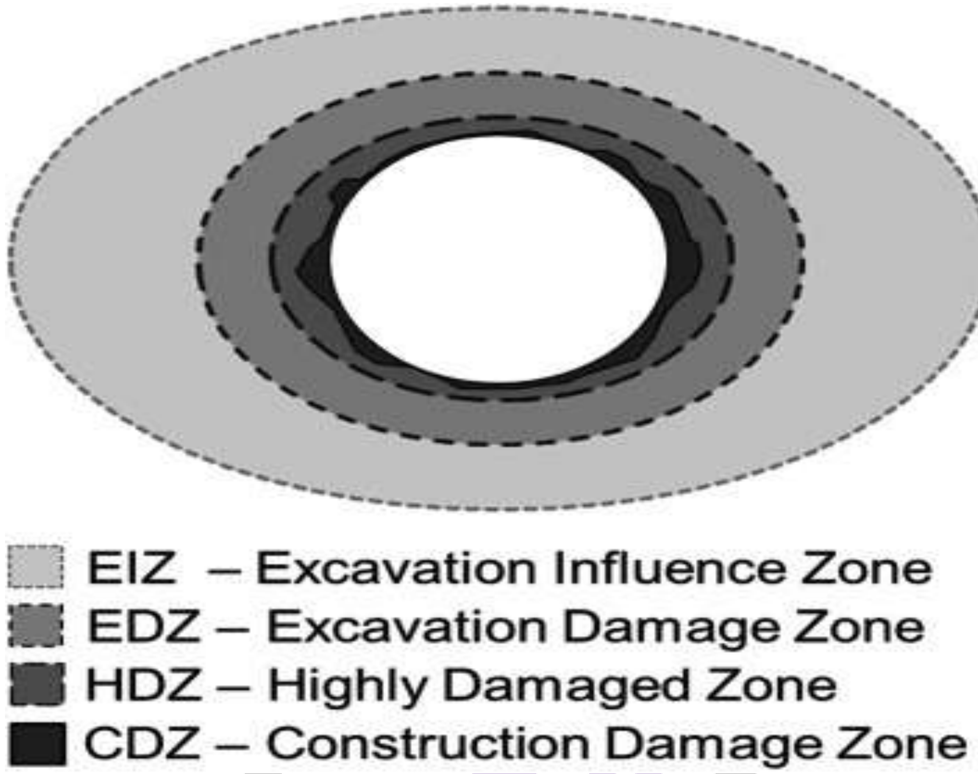

Fig-01

1.3 Highly Damaged Zone-
The Highly Damaged Zone (HDZ) was defined as the part of the EDZ, close to the excavated face, where macro-scale fracturing or spalling may occur. The effective permeability of this zone is dominated by the interconnectedness of the discrete fracture system formed and may be orders of magnitude greater than the undisturbed rock mass

1.4 Construction Damage Zone-
The Construction damage zone is result of construction methodology and changes in properties significantly. The initial inevitable excavation consequence and additional effects induced by the construction method, The latter form of damage, also known as the construction damage zone (CDZ), can be reduced or nearly eliminated by adjusting or changing the excavation method (Martino et al., 2007, Jonsson et al., 2009). In contrast, the inevitable damage can be purely the result of geometry, structure, and/or induced stress changes (independent of excavation method).

I. MECHANISMS OF EDZ

FROM EXPLOSIVE DETONATION IN UNDERGROUND OPENINGS
In the past various definitions of the disturbed and damaged zones have been used. This report uses the definitions of the Damaged and Disturbed Zone proposed by Tsang et al. (2005). The Excavation Disturbed Zone (EdZ) is a zone with hydro mechanical and geochemical modifications, without major changes in flow and transport properties. The Excavation Damaged Zone (EDZ) is a zone with hydro mechanical and geochemical modifications inducing significant changes in flow and transport properties. These changes can, for example, include one or more orders of magnitude increase in (effective) flow permeability. Within the EdZ state variables such as stress, water pressure, temperature, saturation, water chemistry and related properties such as porosity, may be altered by the presence of the opening but these changes are either temporary (e.g., saturation) or do not have a major influence on flow and transport properties (e.g., small changes in porosity due to changes in effective stresses).

When an explosive charge detonates inside a borehole several zones can be distinguished in the surrounding rock: 1) Zone of crushing, 2) Zone of radial cracking, 3) Zone of extension and expansion of fractures and 4) Elastic Zone, where no cracks are formed. The damage that may occur in nearby rock happens behind the elastic zone. Excavation of underground openings by rock blasting methods results in fragmentation within a certain volume that should not exceed the perimeter established in the corresponding design. Deviations of that perimeter from their outside and inside limits are called over break and under break respectively, with the word back break used when over break is excessive. The more general concept of EDZ (Excavation Damaged Zone) applies to the fractured and fragmented rock volumes that surround a cavity upon blasting, also called DOW (Damage to the Opening Wall) by Maerz N.H. et al.,1996. These deviations are normally undesirable because they generate higher costs in the constructive process of the underground opening.

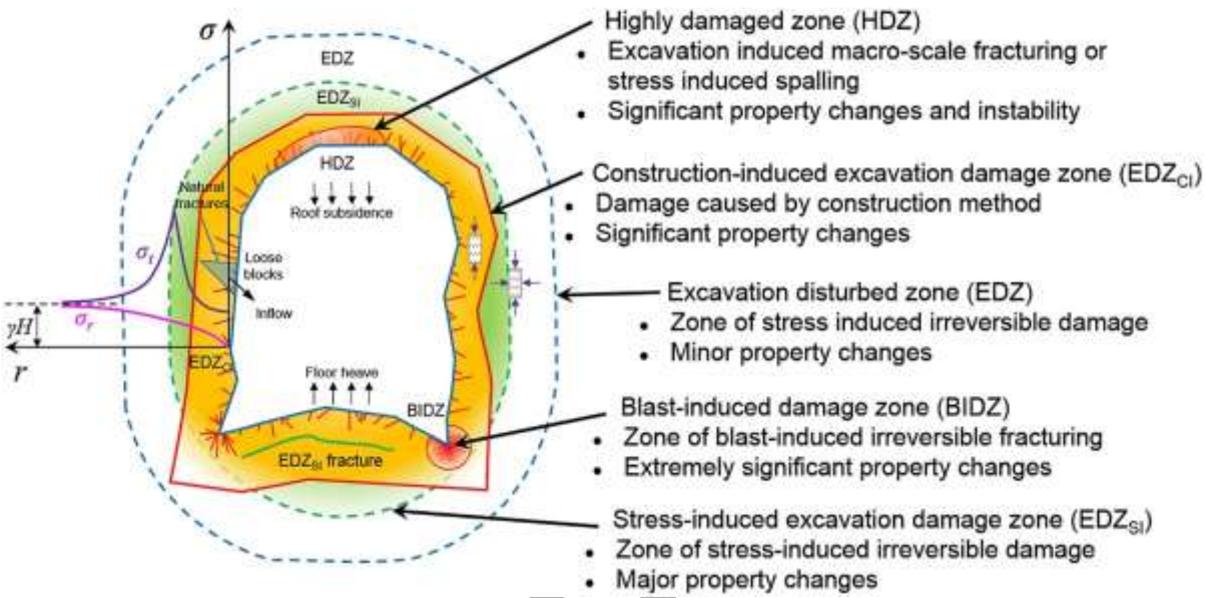

Fig-02

III. PARAMETRIC STUDY

The presence of blast induced damaged zone around excavations has been an important concern during tunnelling. The term excavation damaged zone (EDZ) is taken to mean the disturbed zone that includes the failed and damaged zones closest to the wall that are caused by the excavation method. In this study, the effect of rock condition, tunnel diameter and tunnel depth on the magnitude of the EDZ is investigated through CEL analysis. The TBM advancement velocity and the cutter head rotation rate is 0.1m/s, 6rad/s, respectively. Table 6 shows the typical grading of rock used for tunnel design in Korea based on the RMR grades (Jeong et al. 2014).

The diameter of the tunnel is set to 2.5m, 3.5m and 4.5m. The depth of the tunnel differs by 14m, 39m and 54m. Through analysis, the magnitude of the EDZ is shown separately for the upper, lower and in front of the TBM tunnel. The ground was modelled as a homogeneous rock, since it was found that the homogeneous rock condition yielded the largest EDZ, based on prior numerical case studies. The threshold of the EDZ was assumed as a region where the deviatoric stress due to the excavation exceeds 30% of the original rock mass uniaxial compression strength (Dietrich's 2004)

❖ The Effect of Rock Type:

In this study, the effect of rock type on the magnitude of the EDZ was investigated through series of CEL numerical analysis. As a result, majority of the cases show the EDZ in the front, upper and the lower zone of the tunnel excavation in the range of 0.1D ~ 0.4D, 0.1D ~ 0.4D and 0.2D ~ 0.4D, respectively. However, under extremely hard rock condition (RMR 1), the magnitude of the EDZ in front, upper and lower zone of the excavation surface was up to 0.6D, 0.9D and 0.8D, respectively. The results of the parametric study normalized with the tunnel diameter (D = 3.5m)

❖ The Effect of Tunnel Diameter:

The analysis on the effect of the tunnel diameter on the magnitude of the EDZ was conducted by modelling the tunnel diameter to 2.5m, 3.5m and 4.5m. The effect of tunnel diameter was examined for various rock types. Through series of CEL analysis, the results show that as the diameter of the tunnel increase, EDZ tends to increase as well. However, after normalizing the magnitude of the EDZ with the diameter of the tunnel (EDZ/D), it did not show significant increase due to the increase of the tunnel diameter

❖ The Effect of Tunnel Depth:

The effect of tunnel depth was investigated by modelling a tunnel 14m, 39m and 54m below the ground. By modelling the rock and the TBM operating condition to a constant, the effect of the tunnel depth was analysed under various rock types.

As explained, the magnitude of the EDZ decreased in all direction as the depth increases. In addition, as the tunnel depth exceeds 39m, the tendency of the EDZ decrease constantly and converges to 0. This can be explained based on the gap (crack) closure due to high in-situ earth pressure (Eberhardt 1998)

Table 1. Summary of parametric studies on effect of rock type (Jeong et al., 2014)

Group	RMR	E(MPa)	UCS(MPa)	Poisson's ratio'v'	Specific weight'γ' (kN/m3)	Angle of friction'φ' (°)	Cohesion (kPa)
I	81~100	30,000	90	0.20	27	45	5400
							4000
		20,000	75				5400
							4000
II	61~80	15,000	60	0.22	26	40	3000
							2000
		10,000	50				3000
							2000
III	41~60	8,000	35	0.24	25	35	1500
							1000
							1500
							1000
IV	21~40	4,000	15	0.26	23	32	700
							550
							400
		2,000	10				700
							550
							400
V	<20	1,000	5	0.28	22	30	200
							150
							100
		800	4				200
							150
							100
Weathered Rock	-------	400	3	0.30	21	32	90
							70
							50
		200	2				90
							70
							50

Conclusion

The main conclusions are as follows:

- The excavation damaged zone of an underground roadway is affected by several factors. First, the excavation blasting dynamic load and the unloading effect are the main reasons that the initial EDZ is induced. Subsequent to this, the stress concentration can enlarge the size of the EDZ and the increment of the EDZ limit
- There is an asymmetric distribution regulation of EDZs in the layer rocks, and the size of the EDZ increases by approximately 5%–18% with the excavation progress. In addition, the later excavation zone has a comparatively larger value.
- It is necessary to design the supporting parameters according to the distribution of the EDZ, that is, an asymmetric supporting technology is necessary to maintain the stability
- Compared with conventional multiple linear regression, it can be concluded that random regression algorithms perform well in predicting the EDZ in terms of its explanatory value.
- The delineation of the dimensions of the EDZs is an important factor in the design of underground excavations, particularly when increases in the porosity and permeability of the surrounding rock mass due to the excavation process are to be minimised.
- The method employed herein demonstrates the process from going through laboratory test data for input into numerical models to determining the depth of the EDZs. High-quality geotechnical data from investigations improve the engineering understanding of the rock mass behaviour and with a large sample set, allow for statistical methods to be employed to,

❖ The variation in the EDZs can be used to further refine the design of the underground excavation, considering the likelihood of the dimensions. This method allows for optimisations of the excavation geometry, support, and, most crucially, the depth of cut-off structures in the case of permeability sensitive structures with a certain degree of confidence.

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