

## Earthquake disaster research of shaft and tunnel engineering in mining area

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**ABSTRACT:**In this paper, the authors analyse the characteristics of disaster of shaft and tunnel engineering in mining area, and advance 9 factor coefficients which relate to the disaster. At last, the defence measures are given out.

Fruitful results of the research on ground buildings and engineering constructions have been taken in many countries of the world. However, as the affect of macro-concept that the disaster of shaft and tunnel engineering is lighter than ground buildings, many experts usually omit to research the seismic disaster of them, so many mine constructions are damaged by earthquake, although they can be avoided or lightened by taking some measures. Therefore, the authors consider it is very important to study seismic disaster and defence measures of shaft and tunnel engineering in mining areas.

In this paper, by investigating and analysing shaft and tunnel engineerings of six mine that have been hit by earthquake, The authors sum up the main reasons that lead to disasters of these engineerings, and give out effective defence measures.

### 1 DISASTER CHARACTERISTICS OF SHAFT AND TUNNEL ENGINEERING

By investigating the earthquake disaster of 3.46 million meters long tunnels and 49 shafts of the mines in different intensity areas, the authors find that the disasters have the following characteristics.

#### 1.1 Shaft

Disaster position of the shaft allways is close to the ground. Most of them is within 50 meters under

ground, and can be repaired to use. Its destruction state may be fallen into three types.

i) Inclined or ring crack even fracture and shift

The fractures usually appear at the position where structure are combined or shaft-wall is holed in the Quaternary Period layer.

ii) Vertical crack

The cracks on block is more and concrete less. The shaft-wall peel off at the crack position, and the shaft equipment is damaged and bend.

iii) Cross crack

In the investigation, it is found only a few disasters of this type appear, and the width and loughth is smaller than others.

#### 1.2 Cavern

This caverns are allways used to leave with various equipment. Usually, It is longer and its sections is bigger. The disaster mainly is vault sinking and cracking; surface peeling off; infiltration water increasing; local vault decaying; side-wall cracking and pouting. But the equipment in the caverns is not damaged.

#### 1.3 Main tunnel

The main tunnel is transportation and ventilation adit on each level. The section shape allways is semiarcle vault. Supporting forms are grouted anchor concrete, concrete block, brick arch and union supporting,

etc. The investigations show that the greater part of main tunnels do not take place serious disaster. But the disaster, such as vault sinking, cracking, peeling off, decaying, and pouting of wall and bottom, appear at some local sectors.

#### 1.4 Digging tunnel

The supporting forms of this type tunnel include grouted anchor concrete, U-shaped steele, wood supporting, etc. The disasters are that the sections are crushed out of shape, local vault peeling off, and bottom pouting.

#### 1.5 Shaft bottom vehicle place and intersection

The shaft bottom vehicle place is a hub of transportation. Tunnel, cavern and intersect quite concentrate. The sections are relatively big, and tunnels join each other. Wall rock usually is stable, and it is supported with blocks of stone. The disaster often is not serious. Only the positions, such as the joint between shaft and vehicle place, tunnel intersection, transforming section, take place disasters of deforming cracking, peeling off, or pouting. But vault decay at individual sectors.

#### 1.6 Water disaster

In fact, when some shaft-walls in sand layer are damaged, dropping water will increase, thus the disaster of tunnels that are flooded by water for a long time may accent.

### 2 DISASTER ANALYSIS OF SHAFT AND TUNNEL ENGINEERING

There are many factors that affect the engineering disaster. After a systematic analysing, 9 factors are determined. The statistical data have been analysed according to the regression analysis method that base on method of the minimum squares that have both qualitative and quantitative variable. [1]. The formular is following.

$$Y = \sum_{j=1}^7 \sum_{k=1}^7 \delta(j,k) b_{jk} + \sum_{u=1}^2 b_u x(u)$$

Where,

Y -- disaster index  
 $b_{jk}$  -- qualitative variable  
 $b_u$  -- quantitative variable

In order to be easy to calculate, the results may be transformed as qualitative coefficients, see Table 1. By adding up each coefficients, the disaster index may be obtained, and then the disaster level will be known by looking up table 2. Thus we can know how to take the defence measures.

### 3 DEFENCE MEASURES

According to the disaster characteristics and analysis results, the authors advance following defence measures.

#### 3.1 Rational layout of shaft and tunnel.

Shafts and tunnels are the key parts to mine engineering. They used to be opened in stable rock, and keep away from the fault as possible. The sections aren't admitted of changing within 50 metres under the ground, and avoid to cross few tunnels on any level. The disaster of inclined cross two-brach tunnels is more serious than vertical ones. So tunnels would better be vertical each other, and it is best to make the widest possible use of T-shaped cross. Third-branch tunnels must avoid to be used at one position, and each branch ought to miss another as possible. If technological process require that, seismic check must be taken to joint. In addition, supporting form and thickness must be consistent, and the form which supporting and wall rock work together may be taken as possible.

#### 3.2 Choosing of structure model

Now, the structure of tunnel sections are divided in vertical-wall vault (U-shaped) model, semicircle vault model, parabola vault model and hoof shape vault model. Investigation and analysis show, U-shaped model is convenient to construction, but the seismic capability of it is poor. Semicircle vault model is convenient to construction too, however, the capability is slightly better than the former. The mechanical properties

of parabola vault is fine, so its capability is good, and the construction is not difficult. Although the hoof-shaped vault model also has a good seismic capability, the construction is inconvenient. Therefore, it would be better to take parabola vault for tunnel structures.

For shafts, round section is best.

### 3.3 Union supporting

In all kinds of supporting, grouted anchor concrete supporting have a best seismic capability. Because grouted anchors may control wall rock loose ring, and form common work state.

### 3.4 The best taking of structure size

#### 1. Vertical-wall vault model:

Span  $\leq$  4.5 metre

Vector  $\leq$  2 metre

#### 2. Semicircle vault model:

Radius  $\leq$  4.5 metre

#### 3. Parabola vault model:

Span  $\leq$  5 metre

Vector  $\leq$  4 metre

### 3.5 Handling of wall rock stability.

At sectors of unstable wall rock, tunnels ought to make a special treatment. For example, construction joint can not appear, especially take one-time pouring at multi-branch intersect joint: Increase supporting thickness and ram fine concrete densely. Anchor bar in grouted anchor

structure expose and combine with concrete supportings.

### 3.6 Entrance and exit

Extension size of entrance and exist is decided by slip distance of loose side slope. Suppose the level length that loose side slope slip is L meters. According to calculation, the extension covering thickness should be three times as much as L at least, and the covering thickness of extension part and L metres up to the cavern gate may be added too. The explicit value is determined by calculating soil sample. In ordinary case, it is three times of the tunnel supporting thickness near the gate.

## 4 CONCLUSIONS

The disaster of shaft and tunnel engineering is lighter than ground buildings, but some defence measures must be taken, so that wounded or dead people and economic losses may be increased, the production can be resumed rapidly too.

## REFERENCES

- [1] CHEN Zhongyun, SONG Dong, 1991, Prediction Method of Mine Construction Disaster
- [2] CHEN Shoudiang, WEI Lian, 1988, Earthquake Resistance and Disaster Prevention Countermeasure.

Table 1. Disaster factors and coefficients

Factor	Classification	Coefficient
wall rock	stable	-0.04
	basically stable	-0.01
	unstable	0.12
	very unstable	0.18
fault and fracture zone	seisnogenic fault	0.30
	active fault	0.24
	fracture zone	0.17
intensity	7°	-0.05
	8°	-0.03
	9°	0.11

intersection	T-shaped	0.05	
	+ -shaped	0.00	
	∟ -shaped	0.05	
	× -shaped	0.10	
tunnel ratio of rise to width	$0.5 < H/B < 1.0$	0.01	
	$1.0 < H/B < 1.5$	0.02	
supporting form	grouted anchor	-0.03	
	grouted anchor concrete	-0.04	
	concrete block	0.04	
	wood supporting	0.10	
tunnel depth (m)	< 50	0.025	
	< 100	0.015	
	< 500	0.007	
	< 1000	0.001	
	> 1000	-0.030	
section shape of shaft and tunnel	vertical-wall vault	0.009	
	round section	0.004	
	semicircle vault	0.003	
	hoof shape	0.001	
	parability vault	0.000	
included angle of tunnel and shaft	horizontal tunnel	0.000	
	inssequent tunnel	$\alpha \leq 15^\circ$	0.001
		$\alpha \leq 30^\circ$	0.003
		$\alpha \leq 45^\circ$	0.007
vertical shaft	0.001		

Table 2. Disaster index

disaster	index
intact	< 0.100
basically intact	0.100 ~ 0.125
slightly damaged	0.126 ~ 0.375
mediumly destroyed	0.376 ~ 0.625
seriously destroyed	0.626 ~ 1.000