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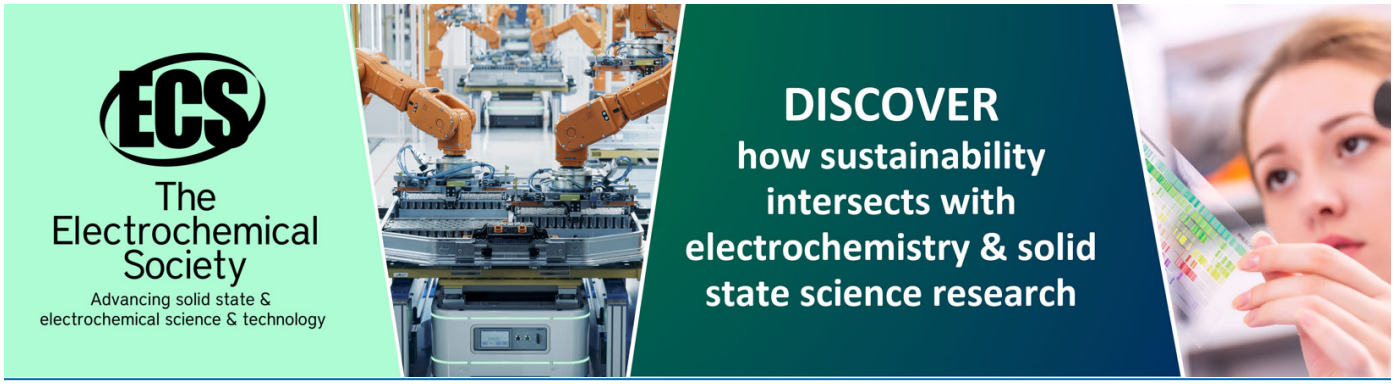

Blasting cushion pad of reducing vibration start a new era of decreasing disaster in civil and mining engineering explosion with micro-damage

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Abstract. Millisecond delayed blasting has been widely used in reducing vibration of engineering blasting practice before. Pre-splitting blasting has been widely used in reducing vibration of rock slope excavation by blasting up to now. There was still damage to surrounding rock by millisecond delayed blasting and pre-split blasting even smooth blasting. The recurrent blasting vibration will produce cumulative damage to surrounding rock mass of underground and rock slope engineering, even induce rock mass fracture , collapse, roof fall or instability landslide . The damage area is much larger than the blasting excavation area, so rock mass would be damaged several times and result in accumulative damage. Not only the disturbance of single blasting on the surrounding rock should be controlled during blasting construction of anchorage roadway or tunnel, but the emphasis should be put on the accumulative vibration effect of surrounding rock induced by frequent circle short-distance blasting and the corresponding control measures should be taken. This paper introduces a cushion pad which has simple structure and is easy used in blasting engineering. This device can not only avoid large amount of cracks on the rock slope and cumulative damage to surrounding rock mass and rock mass of engineering to instability induced after blasting, but also cushion and hold up at large extent heavy detonation shock after blasting. It is first used in Panzhihua Xujiagou iron open pit, Huayinshan coal mine with gas in SiChuan province,

Miaowei hydropower station in Yunnan province and Minshui tunnel blasting engineering in Xin-Fen highway in Hebei –Shanxi province. It effectively cushion the heavy detonation shock from explosion avoiding the damage surface of surrounding rock and accumulated damage of rock, thus improve stability of rock mass and save a large amount of support costs. The vibration velocity with cushion is 50% less than with pre-splitting blasting, even less than the threshold of blasting vibration accumulated damage. Ratio of semi--hole archive 95%. Achieve China patent, the number: ZL 201220107888.5, ZL201220230579.7, ZL 201220750552.0. , ZL 201220016697.8.

1. Introduction

In capital construction and mining engineering, blasting is largely used for mining and civil engineering excavation. Blasting leads to vibration damage and stability problems of underground and vicinal structures such as buildings, bridges, dams, mine workings, tunnel, etc. Uncontrolled blasting generates ground vibration, which caused by the blasting seismic effect is relatively complex, has been trying to solve. The main method of reducing blasting vibration is millisecond delay blasting technology of reducing vibration. As its application in engineering practice show the effects of vibration reduction, it become the main means reducing the intensity of blasting vibration in engineering blasting in application at present. Blasting technology of reducing vibration with millisecond delay still induce damage to wall rock. The length of delay time is impossible delayed endlessly. The paper introduces a cushion pad which has low cost and is simply used in blasting engineering. It is first used in Panzhihua Xujiagou iron open pit. It effectively cushion the heavy vibration from basting with micro-damage of surrounding rock mass and avoiding accumulated damage of rock, The improving slope stability of rock. The vibration velocity with cushion is 50% less than with pre-splitting blasting. The ratio of semi--hole archive 95%. Achieved China patent, the number: ZL 201220107888.5, ZL201220230579.7, ZL 201220750552.0, ZL 201220016697.8. It is also first used in Huayinshan coal mine with gas Sichuan province, Miaowei hydropower station in Yunnan province and Minshui tunnel blasting engineering in Xin-Fen highway in Hebei –Shanxi province.

2. Pre-split blasting

Damage induced from uncontrolled blast weakens integrity of rock mass, leading to loss of stability in the underground excavations. The loosened rock from damage extended few meters in the rock would raise serious safety and stability problems to the wall rock of the underground openings. In the practice of engineering blasting, to reduce the vibration of blasting, in adjacent rock mass slope or surrounding rock, pre-split blasting technology is used almost and gets better effect at present. When the precutting free surface is applied, the reduction rate becomes 50%, suggesting that the precutting free surface reduces blasting-induced vibration significantly. In summary, most of the blasting-induced vibration is reduced with the aid of a precutting free surface. [1].

3. Pre-split blasting compared with blasting with cushion pad

Compare of pre-split blasting with blasting with cushion pad was done in Panzhihua Xujiagou iron open pit in Sichuan province. Panzhihua Xujiagou iron open pit is close to the south of Jinsha River. Final slope angle 0f stope is 48°～53°, stage height is 12m, width of platform is 5m～10m. The Protodyakonov coefficient of rock f is 8–10 and is not intact. The rock geology contains a large amount of very complex fractures. Most of rock mass suffered from damage induced from blasting. Test zone of blasting is divided to two zones, one is explosive charges with cushion pad at the shots, another is pre-split blasting without cushion pad. Explosive charges at the shots are furnished with cushion pad near reserved slope in one of test zone. As shown in Figure 1, it was vibration measure map with cushion pad charge after blasting, 20 meters from blasting center.

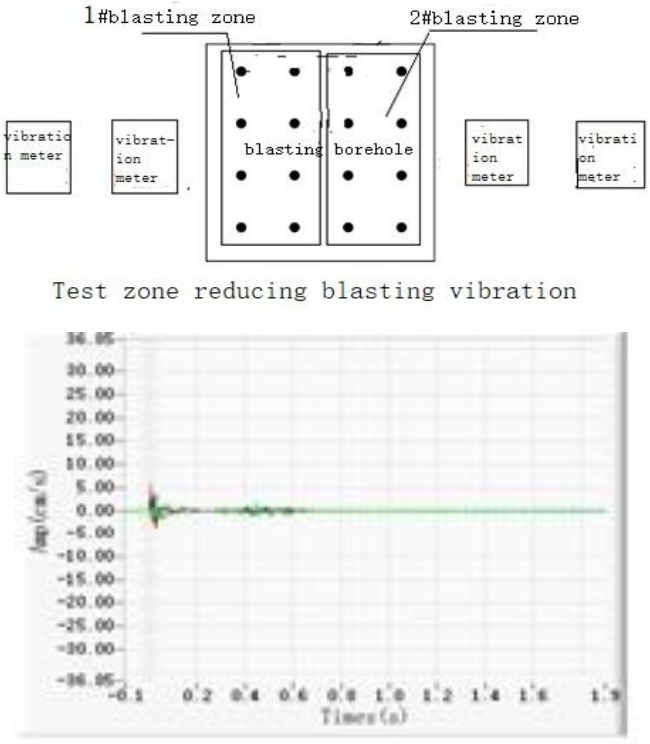

Figure 1. Vibration measure map with cushion pad charge after blasting, 20 meters from blasting center.

As shown in Figure 2, it was vibration measure map with pre-split blasting (without cushion pad charge) after blasting, 20 meters from blasting center.

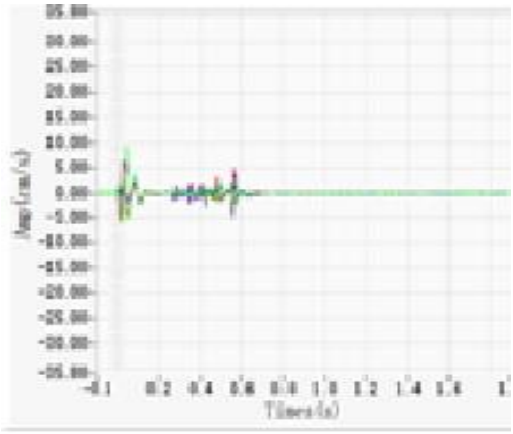

Figure 2. Vibration measure map pre-split blasting (without cushion pad charge) after blasting, 20 meters from blasting center.

As shown in Figure 3, it was the comparison of pre-split blasting with blasting with cushion pad.

Figure 3. Comparison of pre-split blasting with blasting with cushion pad.

Left (1#) is the zone of blasting holes charged with cushion pad after explosion. The ratio of semi--hole achieved 95% on rock slope of open pit. Right (2#) is the zone of shot holes with pre-split blasting. There are random radial cracks damage even over-break near the surrounding rocks and no almost semi-hole.

The dynamic loadings generated by recurrent blasting operations will inevitably bring cumulative damage to surrounding rock mass and even induce rock mass of underground engineering to instability. [2]

Engineering blasting destroys stress state and structure of the original rock, thus affecting the stability of the retained rock mass and surrounding rock, numerous accidents occurred in the open - air slope and underground civil & rock engineering.

Landslides, damage of bedrock, and failure of underground rock structure are the usual disasters induced from blasting vibration. It is very important to the stability of rock mass (underground) under dynamic load，for it directly related to the safety of the project-self.

Figure 4. In 2003, Zhujiabao iron open-pit of Panzhihua Steel Group (Sichuan province), blasting induced slope slide.

As shown in Figure 4, the slope slide induced from blasting vibration entailed a loss of CNY 60 million.

In the dam foundation excavation with blasting, there was a massive collapse induced from blasting vibration at the left bank slope of YUNNAN MANVAN hydropower station. [3].

In order to reduce or eliminate the overbreak, protecting the surrounding rocks effectively, the vibration effect of explosions is substantially mitigated by cushion pad.

For the cushion pad can be greatly block and buffer explosive huge impact on the rock mass, the most of the blasting energy consumed in the region of the crushing area and crack area buffered and blocked, it greatly reduce the explosive vibration of slope rock mass.

Substantial progress has not been attained in the study of repeated exposures of dynamic loading on jointed rock mass in comparison to conventional blasting with single episode of loading. It was reported that rock mass subjected to repeated blast loading resulted in relatively excessive damage than a single fold blasting. After repeated exposures of vibrations due to main tunnel, blast loading could produce displacements and extra damage pre-conditioning in the rock mass even at lower levels of vibrations than the Vcr [4].

Findings of Adamson and Scherpenisse (1998) says that of threshold vibration level falls down to 25% of Vcr in repeated loading conditions [5], which stated that the vibrations above 50% of Vcr can cause damage during repeated blast loading [4].

The vibration velocity with cushion pad is 50% less than with pre-splitting blasting. If slope angle of open-pit iron mine increase 1 degree, the total amount of stripping rock will be reduced hundreds of millions of tons, hundreds of millions of RMB will be saved [6].

The shock vibration on rock mass with blasting cushion pad will be less than threshold vibration and could improve stable angle of rock slope.

If cushion pad is made of better cushion material, rate of reducing vibration would reach about 100%. There will be almost no breaking of surrounding rock mass with cushion pad.

Cushion pad of reducing blasting vibration is the best way to decrease disasters induced from blasting vibration.

4. Blasting with cushion pad is used in other projects

Ratio of semi--hole achieves 95% on the rock slope of Miaowei hydropower station in Yunnan province (Figure 5), also achieves 95% on the rock of tunnel (Figure 6) [7].

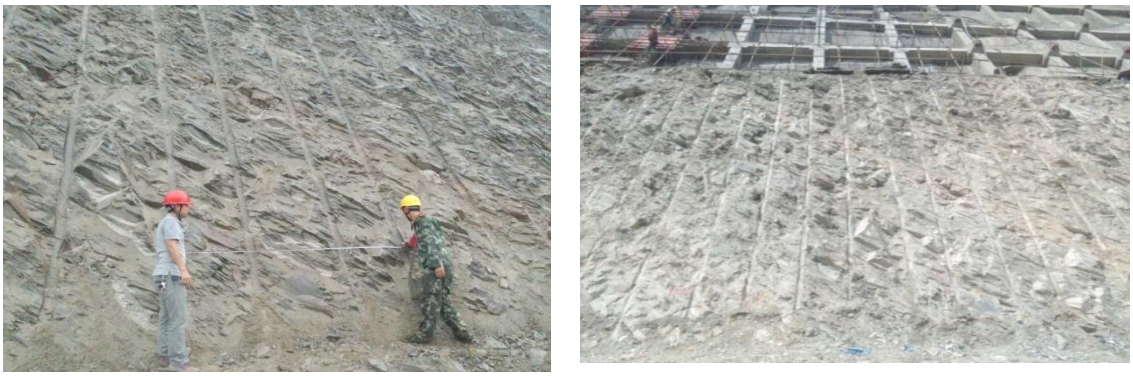

Figure 5. Semi-holes on the rock slope after explosion with cushion pad.

Figure 6. Semi-holes on the rock of tunnel after explosion with cushion pad.

From Figure 6, there are almost no breaking on surrounding rock with cushion pad, with micro-damage and no circle of loose and crack. Blasting cushion pad absorb and isolate the vast majority of total energy of blasting shock wave.

If wall rock mass has itself-sustaining strength that no support needed, supporting arise only from the failure of wall rock. Forces of rock mass volume swelling caused by failure of wall rock give rise to deformation and failure of supports.

Not only in coal mine, but also in the metal or non-metal underground mine production, the most common accident is roof collapse accident, which occupy area of about more than 40% of the mine production safety accidents. Roof collapse accident of more than 40% was caused by inferior blasting in roadway construction and most of them occurred within 1-2 hours after blasting. So do accidents of slope slide [8].

The above statements are supported by engineering practice. As all road ways without support, failure zone is almost close to zero, elastic-plastic deformation still exists, need no support.

For example, north of Shan Xi province, loess cave dwelling is excavated by hand, no blasting vibration. Although loess compression strengthen is only 0.2MPa, there is no damage to wall loess induced from blasting, most of them can be used more than 100 years.

Blasting cushion pad will save lots of supporting cost.

As shown in Figures 7 and 8, blasting cushion pad was used for demolition of reinforced concrete support beam with blasting .

Figure 7. Reinforced concrete support beam blasting demolition photo.

Figure 8. Photo of reinforced concrete beam after blasting.

5. Invention of blasting cushion pad

The invention of blasting with cushion pad was inspired through directional fracture controlled blasting with slotted charge and shaped charge.

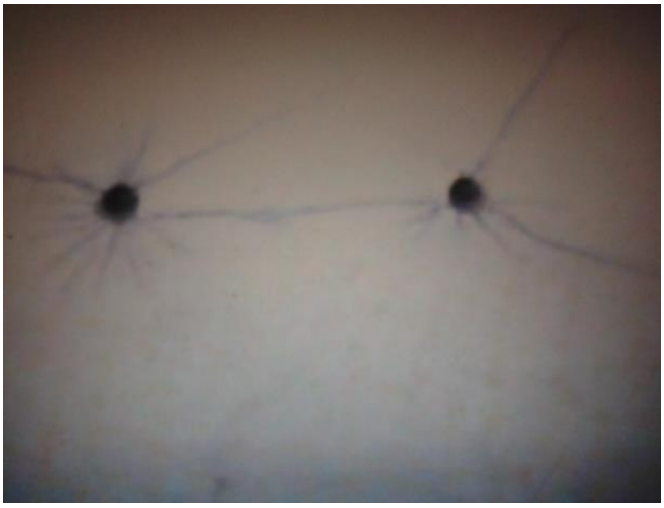

Figure 9. Blasting effect photo without slot (shaped) charge.

Figure 10. Blasting effect photo with slot (shaped) charge.

From Figure 9, there is not only penetrating fracture (crack) between bore holes of pre-split (smooth) blasting, but also random radial fracture (cracks) near the holes in other directions. Random radial cracks damage the wall rock mass, even result in over-break especially in soft rock.

In directional fracture control blasting with shaped (slotted) pipe charge; only one crack is penetrated along the line of bore holes. The penetrating crack in directional fracture blasting (Figure 10), similarly, which is different from pre-split (smooth) blasting. The charge in shaped (slotted) pipe brings about a directional explosion load to rock. This load results firstly a directional crack in the direction of linking line along bore holes and reduces lot of random cracks [2,9-11].

The technology of directional fracture controlled blasting with slotted charge and shaped charge (linear bilateral cumulative energy) in roadway of coal mine is used largely. Combining with technology of seismic reduction and isolation of architectural structure, the blasting with cushion pad was invented [2].

Directional fracture controlled blasting with slotted charge and shaped charge (linear bilateral cumulative energy) achieved national technology (invention) prize of China (1996, 2018).

The mechanism of blasting cushion pad is very different from directional fracture controlled blasting with slotted (shape) charge.

6. Conclusion and future work

The prevention and control of stope rock-burst (tunnel), which is still at the research and exploration stage, should run through the whole mining process. The break-tip blasting in deep hole with shaped (slotted) pipe charge (blasting cushion pad) ultimately changes the stress distribution of goaf roof and markedly decreases rock bursts in the effective range of blasting and reduce subsidence of roof and Surface.

Blasting cushion pad not only avoid lots of cracks and cumulative damage on rock slope and wall rock, but also cushion and isolate detonation shock wave from blasting. When blasting cushion pad is used in rock excavation, there will be huge economic and environmental benefit. In Quarrying and Cutting of stone mining, smoothing and pre-split blasting will inevitably leads to micro-damage and crack problems. Blasting cushion pad can solve them except along the line of borehole. Blasting cushion pad can also be used to reduce the peak pressure of shock wave of underwater, for example, the embankment method of stone filling with blasting squeezing silt, marine reclamation land. It was concluded that it would cut down the size of blasting crack zone and decrease breakage degree of radius damage region of surrounding rock, would raise the self-supporting ability of surrounding rock through blasting with cushion pad, so as to make the rock support structure of roadways stable so as to the surrounding rock (soft) mass. Blasting cushion pad will be used for excavation of mining and civil engineering. Cushion pad of reducing blasting vibration start a new era of decreasing disaster of civil engineering and mining (especially soft rock).

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