Analysis of belt bridge mode and blasting vibration response spectrum in a mine

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Abstract. With the wide application of blasting technology, people pay more and more attention to the impact of blasting vibration on the surrounding environment and buildings. To blasting vibration analysis and evaluation of the effect on the stability of the skip shaft, belt bridge based on the large finite element analysis software ANSYS Workbench entity unit model, the belt of the bridge structure modal frequency and applying 2 cm/s numerical simulation of blasting vibration load was the response of the study. The calculation results show that the maximum stress value is 0.0063 MPa, belt bridge in belt bridge at the top of the column, in the concrete design tensile strength of 1.43 MPa. The maximum strain of the belt bridge is 5.05×10^{-8}, which is within the allowable elastic deformation range of the building, and is far less than the ultimate tensile strain of C40 concrete 1×10^{-4}. The skip well is in a stable state.

1. Introduction
Blasting is through the release of explosive energy to break the media around the hole. At the same time, due to the blasting stress wave effect, distant media produces shear and tensile stress renders media to produce fissures; the remaining part of the energy in the form of seismic waves spread to the distant media, causing the vibration of the mass point, forming a blasting earthquake. Due to the limited space available in underground mines, the harmful effects of blasting can have disastrous consequences. Therefore, in the event of a major blast in an underground mine, the harmful effects of the blast must be controlled, prevented and monitored as necessary as possible. With the widespread use of blasting technology, people are also becoming more and more concerned about the impact of blasting vibration on the surrounding environment and buildings. Blasting vibration hazards have become a major issue of increasing concern in engineering and academia. It has been realized by relevant scholars around the 1950s that if one wants to evaluate the destructive capacity of a blast earthquake on a building, one has to identify parameters that are important for describing the strength of the blast earthquake wave, which should be easy to measure, and the selection of parameters must be highly correlated with the blast earthquake effect in order for the parameters to be meaningful and easy to apply[1]. Crandell first linked the monitored energy ratios to building damage and used the energy ratios to define the propagation equations and damage criteria for seismic waves. Thereafter, Morris and Westwater performed statistical regression on seismic wave amplitudes and established the formula based on the previous research[2].

Langefors, Edwards, and Worthwood examine the hazards to buildings caused by the blast of an evil-doer, summarizing the different degrees of action at different speeds, and the degree of damage that can be caused to buildings at different speeds. In addition, Nadolski, through his research on the vibration
effects of the ground surface during blasting, concluded that in defining the safety of blasting effects, it is unscientific to use the internal mass point data indicators of the building and should be based on the vibration data measured on the ground adjacent to the building[3].

The impact of the blast on its surrounding rock media and the combined action of the rock media determines the performance of the blast seismic wave, and in some ways determines the impact of blast fragmentation and blast disturbance on the rock. The vibrational effect of seismic waves on the mass point during bursting is divided into two phases: first, the forced vibration phase, which exhibits strong shock properties and has a short duration, and second, the free damping vibration phase. In the process of testing and analyzing the signal, it is difficult to extract the short-term forced vibration signal, resulting in the extracted frequency feature only containing free damping vibration, while the maximum vibration speed of the forced vibration stage reflects the peak vibration speed of the mass point, and the incomplete frequency feature cannot provide more comprehensive vibration data, making it difficult to consider all aspects when establishing the safety criteria of the frequency feature. Therefore, in order to reduce the negative effects of blast vibration on the building, the loading and transfer of blast shock energy from the blast phase to the building (structure) should be controlled. At this stage, blast charge adjustment and differential blasting techniques are usually used to reduce the damage of blast vibrations to buildings, and sometimes pre-cracking blasting is also used to reduce the intensity of blast seismic waves[4].

In the case of unchanging geological conditions, the intensity of the blasting seismic wave is closely related to the type, amount, method, concentration and detonation form of explosives, etc., thus these factors refer to as the charging conditions. The different charging conditions affect all aspects of the blasting process, ultimately leading to the blasting seismic wave showing different characteristics, which in turn affect the effect of blasting. Thus, the objective of effectively reducing the negative effects of blast seismic waves can be achieved by adjusting the loading conditions[5].

2. Building a finite element model of a belt bridge

The load-bearing members consist of supporting columns. The main construction material is C40 concrete. The overall reinforcement rate is 1%, as shown in Figure 2.1.

![Figure 2.1 Site photo of a mine belt bridge](image)

According to the drawings, the belt bridge is divided into two sections. The simulation selected one of the modeling form is monolithic modeling[6]. The mechanical parameters of the concrete and reinforcement are equivalent to the treatment. The treated reinforced concrete equivalent spring mode is 32500 MPa. Poisson ratio is 0.2 and density is 2500 kg/m3. The height direction of the finite element model of the belt bridge is the Z-axis and the Z-axis is perpendicular to the XOY plane. Since the finite element calculation process involves the input of the waveform spectrum, in order to obtain reliable results. While considering the speed and calculation accuracy, the simulation is based on the tetrahedral grid division using advanced functions. The finite element model of the belt bridge[7] and the grid division in ANSYS Workbench are shown in Figures 2.2 and 2.3, where the total number of nodes is 4370 and the total number of cells is 1833.
3. Modal analysis of the belt bridge

In order to avoid resonance problems with belt bridges under various operating conditions, it is often necessary to calculate the modal frequency and vibration pattern of the belt bridge. In this section, the inherent frequencies and vibration patterns of belt bridges are analyzed using the free mode analysis method[8], where no load is added to the free mode. The first six orders of non-zero modal frequencies of the extraction are shown in Figure 3.1.

The first six orders of modal vibration are shown in Figure 3.2 to Figure 3.7.
The characteristics of the vibration pattern changes that occur in the belt bridges in the above figure are shown in Table 3-1.
Table 3.1 Belt bridge vibration shape characteristics

| Order (of magnitude) | Inherent frequency (Hz) | Vibration characteristics                                      |
|----------------------|-------------------------|-----------------------------------------------------------------|
| 1                    | 1.9061                  | X-directional vibration with maximum deformation at the end of the corridor |
| 2                    | 2.1072                  | X-directional vibration with maximum deformation at the corridor |
| 3                    | 2.3618                  | X-directional vibration with maximum deformation at the top of the corridor |
| 4                    | 9.9969                  | X-vibration torsional coupling                                  |
| 5                    | 10.545                  | Y-vibration torsional coupling                                  |
| 6                    | 12.182                  | X-Y torsional coupling at 45°                                   |

4. Belt bridge blast vibration response spectrum analysis

In engineering practice it is necessary to understand the maximum values of displacement and acceleration of the system vibration, i.e. the maximum response of the belt bridge to engineering blast disturbance[9]. The relationship curve between the maximum response value and parameters such as excitation time is called response spectrum[10]. Seismic analysis of belt bridge structures using response spectrum analysis can be performed using the response spectrum module in ANSYS Workbench, an analysis technique for calculating model stresses that closely relate modal analysis results to known spectra. There are mainly single-point and multi-point reaction spectroscopy analysis. Specifying a response spectrum response on a set of points in the model is a single-point response spectrum analysis; specifying different response spectrum responses on different sets of points in the model is a multi-point response spectrum analysis. In this paper, a single point reaction spectral response analysis was performed with the burst vibration velocity spectrum acting in a vertical direction and applied to the eight bottom fixed pivots of the belt bridge respectively. Long-term site monitoring, measured the maximum blast vibration speed of 2cm/s, according to the "Blasting Safety Regulations"[11], the maximum permissible safe vibration speed of a general building under low-frequency conditions is 1.5~2 cm/s, so the maximum permissible safe blasting vibration speed of 2 cm/s loaded in the model for numerical simulation calculations. Study the dynamic response of the belt bridge, and judge the stability of the response structure, and at the same time, evaluate the impact of the field measured vibration on the stability of the belt bridge, whose spectral data is shown in Table 4.1.

The iso-force cloud diagram, strain cloud diagram, general deformation cloud diagram and X, Y and Z-directional displacement diagram of the belt bridge under the loading of the blast vibration wave are obtained by the corresponding numerical calculation.

![Figure 4.1 Equivalent Stress Cloud Diagram of Belt Bridge under Vibration Response](image)

The maximum stress of the belt bridge is 0.0063 MPa, which occurs at the top column of the belt bridge, where the design tensile strength of the concrete is 1.43 MPa. From the calculation results, the dynamic response strength of the belt bridge is much less than the design safety value and will not cause damage to the overall structure of the belt bridge; from the strain cloud diagram, it can be seen that the
maximum strain of the belt bridge is 5.05×10^{-8}, which is within the allowed elastic deformation range of the building, and is much less than the limit tensile strain of C40 concrete 1×10^{-4}, which will not affect the stability and structural safety of the belt bridge.

| Frequency (Hz) | Velocity (cm·s^{-1}) | Frequency (Hz) | Velocity (cm·s^{-1}) |
|---------------|-----------------------|---------------|-----------------------|
| 0             | 0.03776               | 15.63         | 0.5019                |
| 1.465         | 0.01165               | 16.11         | 0.4449                |
| 1.953         | 0.01181               | 16.6          | 0.6112                |
| 2.93          | 0.04583               | 17.09         | 0.6701                |
| 3.906         | 0.04684               | 18.07         | 0.4431                |
| 5.371         | 0.04223               | 19.04         | 0.4435                |
| 5.589         | 0.4935                | 19.53         | 0.268                 |
| 6.348         | 0.6356                | 20.02         | 0.1579                |
| 6.836         | 0.6311                | 20.51         | 0.2109                |
| 7.324         | 0.3509                | 21.48         | 0.1019                |
| 8.301         | 1.156                 | 22.46         | 0.4802                |
| 8.789         | 1.203                 | 22.95         | 0.5443                |
| 9.277         | 1.02                  | 23.93         | 0.2708                |
| 10.25         | 2.022                 | 24.41         | 0.203                 |
| 11.23         | 0.6935                | 24.9          | 0.25                  |
| 12.21         | 1.298                 | 25.39         | 0.3498                |
| 12.7          | 1.168                 | 25.88         | 0.3994                |
| 13.18         | 0.4892                | 26.37         | 0.3332                |
| 13.67         | 0.2736                | 26.86         | 0.1012                |
| 14.16         | 0.5712                | 27.34         | 0.2323                |
| 14.65         | 0.2206                | 27.83         | 0.1957                |

Figure 4.2 Strain cloud diagram under belt bridge vibration response

Figure 4.3 Strain cloud diagram under belt bridge vibration response
5. Conclusion

In this paper, the effect of large blast on the belt bridge is analyzed by numerical simulation, and the steady state of the belt bridge under blast vibration load is judged by simulating the maximum dynamic response strength and maximum strain of the belt bridge under 2 cm/s load, and the following conclusions are drawn:

- A blast vibration wave with a maximum velocity of 2 cm/s is introduced to the surface building belt bridge to analyze its dynamic response under the vibration load. The maximum power response strength of the belt bridge is 6.3×10^{-3} MPa, which is much less than the design safety value.
- From the strain cloud diagram, it can be seen that the maximum strain of the belt bridge is 5.05×10^{-8}, which is within the permissible elastic deformation range of the building, and is much smaller than the ultimate tensile strain of C40 concrete 1×10^{-4}, so the building is in a stable state.
- Since none of the maximum velocities measured in the field exceeded 1.1 cm/s, the vibration loads generated by the blasting activity at this stage will not affect the stability and structural safety of the belt bridge, nor will they cause damage to its strength performance.
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