Damage on Masonry Walls due to Blast Vibration

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Abstract

When the energy left over from a blasting process transmits to the surrounding, particles in their paths are displaced by these waves giving rise to particle velocities. But a structural vibration may vary according to the soil type, soil structure interaction and characteristics of the structure.

Therefore need of a threshold, applicable to our conditions on which to base the blasting operations was identified. This paper presents a study on investigating the damage on wall panels due to blast vibration. A wall panel, size of 1200 mm×1000 mm with free ends and another with vertical lateral supports were constructed closer to a rock blasting quarry and the effect of vibration on the structure was monitored. A significant crack was observed at the foundation level of the cantilever type wall panel at a vibration level around 30mms-1 of ppv but no damage on the wall panel with fixed ends. Numerical modeling was carried out with the Finite Element Modeling using SAP 2000 software. Results of the numerical study verify that the tensile stresses of the bottom level of the wall panel exceed the splitting tensile strength only in the wall panel with free ends.

1. Introduction[1]

Blasting is most commonly used for rock fragmentation in the construction industry. For these blasts, the industry use explosives such as ANFO (Ammonium Nitrate and Fuel Oil), dynamite, TNT etc. It is a process of detonating explosives charged into holes drilled in the rock.

It is expected that rock blasting in a project area for construction raises many public complaints or protests. For example, in Hambantota harbor project [1] and the Southern Transport Development Project [2] many complains have been raised on rock blasting activities.

However, it is questionable whether all of the cracks and structural damages are induced due to the blasting activities.

Even though there are interim standards on vibration pollution and control that vary according to the type of structure [3], they may also vary according to factors such as site conditions, soil type etc. Therefore, the

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need of a threshold, applicable to our conditions on which to base the blasting operations was identified.

Peak particle velocity (ppv) was used for the measurement of the received energy. In previous studies, it has been found that it would be the best measure of a blast vibration [e.g.4].

In the present study, the damage on wall panels due to blast vibration was investigated. Generated ground vibration was measured simultaneously with structural response. Finite Element model analysis was done by subjecting the models to vibration induced by blasting and the model's response was compared with the experimental findings.

2. Methodology

Initial site investigations were done and vibration levels were measured at different locations to select a location for the construction of the experimental model.

A brick wall panel with free ends having a size of 1200 mm × 1000 mm was cast at the selected quarry at Hapugala). The model brick wall panels were constructed using a rubble foundation and stretcher bond of 1:5 cement:sand mortar. A 10 mm thick plaster with 1:1:9 lime:cement:sand was used. After observing initial damage, the damage was repaired and restored for further investigations.

Another wall panel was constructed close to the above model using the same material and dimensions but with vertical lateral supports. The behaviour of the model structure subjected to blast vibration was observed (Figure 1).

Recorded vibration using the seismograph (Blastmate III) was produced into an event report. The event report includes transverse, vertical and longitudinal vibrations and noise induced by the blasting.

Figure 1: Measuring ground vibration using a seismograph

Then the experimental model structures were idealized and modeled in FEM using SAP 2000 software using shell elements of 100mm×100mm.

The same dimensions as of the experimental model (i.e., 1200mm× 1000mm) were selected for the models and it was assumed that the plaster remains as a linear elastic material until cracking. For the constructed wall panel with free ends the bottom boundary was considered to be fixed and three sides for the wall panel with vertical lateral supports. A new material which closely represents the properties of 1:1:9 lime:cement:sand plaster was defined.

The event report of the particular blasting event which caused damage was obtained using the Blastware software. Among the three vibrations and noise level, vibration in longitudinal direction was selected as it was always dominant in affecting the structure (Figure 2).

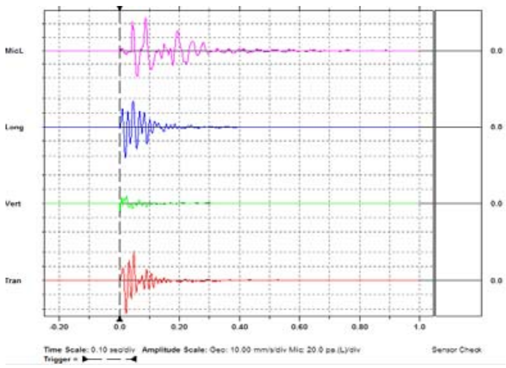

Figure 2: Vibration in three directions and noise level measured using the seismograph

The response spectrum of the event was obtained using 'Piecewise exact method' using MATLAB [5] [6] [7]. Then the available response spectrum of the SAP 2000 software was modified to be representative of the obtained graph. Then the response spectrum analysis was carried out for the models.

3. Results and Discussion

Even though blasting activities were carried out, initially no damage was observed at the structure.

Continuation of blasting has resulted in a significant crack between the wall and the foundation of the first model structure which did not have any vertical lateral supports at a vibration level of 30.2 mm/s of ppv at a frequency of 50 Hz. FEM. After the joint was concreted and restored, significant crack (i.e., a structural separation) was formed at the top level of the concreted foundation.

In contrast to this observation, the wall panel constructed with vertical lateral supports experienced no damage to the structure at the same range of vibration.

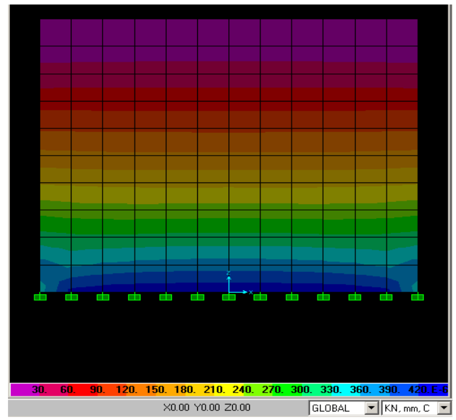

Figure 3: Stress distribution obtained from analysis for cantilever type wall panel

Figure 3 shows the stress distribution along the structure without vertical lateral supports when exposed to the response spectrum of dynamic force. The results of the numerical model using SAP 2000 highlighted an increased S22 stress concentration of about 420x 10^{-3} N/mm^2 at the bottom level of the structure. But according to the results of the model analysis for the structure with vertical lateral supports, the maximum S22 stress level of the model was only about 112x10^{-3} N/mm^2.

The vibration magnitude which caused damage to the structure is similar to the magnitude reported in a previous study in which safety of low-rise residential structures from vibrations generated by mining blasting was investigated [4]. In their study, surface cracks were observed whereas in the current study, a significant crack at the bottom of the structure was observed. This different might be attributed to the low stiffness of the structure used in the current study. Another previous study has identified structural cracks even below 2mm/s ppv (frequency range of 10-50 Hz) in which the vibration considered was a continuous vibration over a long period of time and the wall panels were having openings [8].

An increased S22 stress concentration of about 0.42 N/mm^2 observed at the bottom level of the plaster was closer to the splitting tensile strength of 0.402 N/mm^2. This implies that crack formed at the bottom of the cantilever type structure was possibly due to the greater tensile stress developed at that level.

4. Conclusions

A cantilever type wall panel is susceptible to a structural failure from the foundation at a blast vibration level of 30.2 mm/s of ppv at a frequency of 50 Hz which has been supported by FEM modeling. The significance of having vertical lateral supports in resisting lateral dynamic loads is supported by the observed experimental behavior of the model structure with vertical lateral supports and the results of its FEM modeling which had no stress level exceeding the splitting tensile stress of the plaster.

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