SIMULATION OF IMPACT BEHAIVIOR ON ROCKFALL PROTECTION FENCE

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1. INTRODUCTION

Today, in the medium energy range, flexible barriers like nets or fences have been widely used against rockfall (Photo 1). Because these structures have many advantages namely, low construction cost, quick installation and maintenance, efficiency, reliability, low environmental effect, etc.(Volkwein et al (2011) and Vogel et al (2009)). In order to make clear the performance of this kind of protective structure as well as to enhance its bearing capacity, many field experimental studies and also various numerical studies have been done. These experimental studies mostly had been done using limited typical structures such as a new prototype or a new component of structures. Based on fundamental information from experiments, numerical studies enabled to widen investigation domain and optimize structure design as well as to understand better the behavior of rockfall impacts on flexible barriers (Volkwein et al (2011)). Generally, several real experiments are necessary to evaluate the structural safety. If there is a reliable equivalent numerical method to simulate the behavior of such a protection structure, the number of such experiments could be decreased. From the view given above, this research had been achieved by mean of simulation method using finite element dynamic code based on the series of impact experiments of three spans cable-net fence.

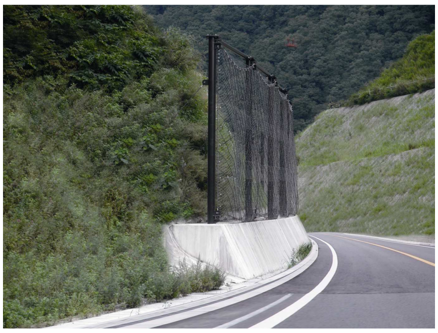
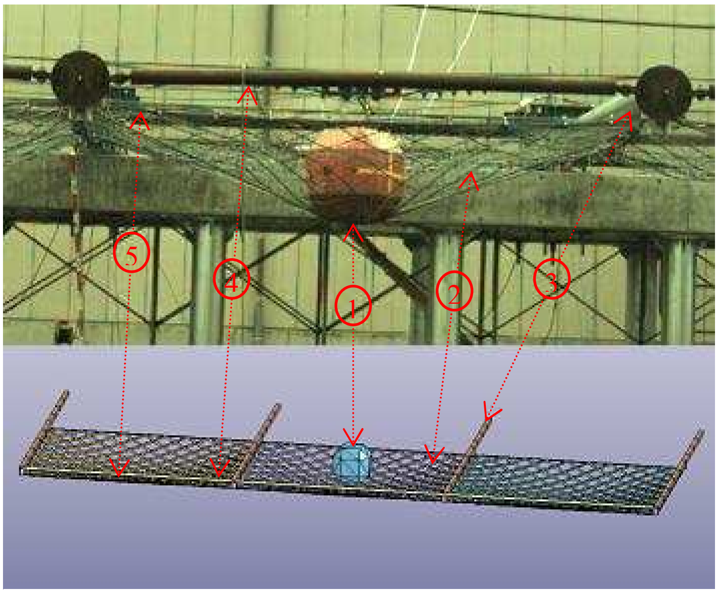


Photo 1 Protection fence

2. OUTLINE OF EXPERIMENTS

Upper part of Fig. 1 shows the experiment of three spans cable-net fence (Nishita et al (2011), Nishita (2012)). A 1 ton mass generated 100 kJ of impact energy by free falling from 10 m height. Impact force was obtained by multiply weight mass by acceleration measured by accelerometer in the center of weight. Three span nets were created by ϕ 12 mm diameter wire cables and friction sliding mesh joints. These nets were supported by ϕ 22 mm diameter guide cable system through U bolt fastenings. Four high strength posts – main load support structures were fixed on two concrete beams at two positions where were also installed two load-cells to measure transmitted loads. Many trusses were installed in two rows at top and bottom of posts to constrain horizontal movement of posts, and also to enhance stability of structure.



1: weight, 2: nets, 3: posts, 4: trusses, 5: guide cables

Fig. 1 Experiment of fence and numerical model

3. NUMERICAL MODELING

To simulate impact on the wire net, LS-DYNA dynamic code with various kinds of material and element models for separate components was used. Discrete beam element and nonlinear elastic material model based on stress versus strain relation were used for all components of cables. Belytschko-Schwer beam element and nonlinear elastic material model with user-defined moment curvature and torque-twist were used for the posts. Results of experiments were utilized to determine proper modeling and material constitutive laws of steel beams and cable in this study. The weight was modeled by solid elements which were elastic material model. Many kinds of contact model between weight and nets, nets and guide cables and mesh joints were been

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setup. This is not only to reproduce exactly mechanical reaction between each two components but also allow one to gather impact force of the boulder on the net. The numerical model is shown in the lower part of Fig. 1. This study also performed a range of parametric studies by changing stress – strain constitutive relationship of cables and designing suitable damping curves for each components.

4. RESULTS AND DISCUSSIONS

Fig. 2 and 3 illustrate a comparison between impact force and reaction force histories from experiment and simulation, it could be said that they are quite good agreement. Maximum value and time duration of impact loads are almost the same, however, it is easy to see that time duration of high values of impact from simulation is smaller than those from experiment (Fig. 2). This leads to be lower impact impulse from simulation than that from experiment. Figure 3 shows reaction force histories measured and calculated at the bottom positions of two mild posts. It is clear to recognize that the peaks of the first wave of reaction forces measured on post number 2 (LC2 and LT2) from the test are about 100 kN larger than these values from analysis (this could be caused by asymmetry), by contrast, the good agreement is easy to observed from the remains of reaction force histories.

From parametric study, it could be thought that damping factors play an important role not only during impact but also before and after impact. Therefore, it is better to analyze eigenvalues for separate components first, this allows one to determine possible range of damping value. Then some curves of damping values in the relationship with time should be defined based on working state of each part.

The maximum value of displacement from numerical calculation is about 30 cm smaller than its from the test. This could be explained based on the differences between numerical model and real test model. The cable nets sagged down by only self-weights, this means that cable sections of meshes could not be straight, typically at friction sliding mesh joints and bends to connect nets with guide cables by U bolt fastenings. Such this characteristic was not taken into account in numerical models. However, it is difficult to judge how much of different ultimate displacement value is reasonable.

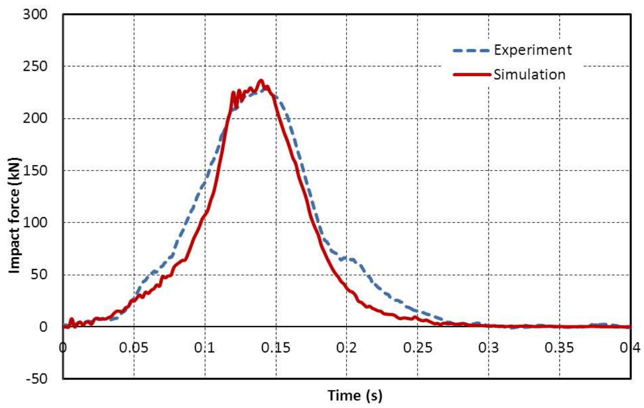

Fig. 2 Impact force history

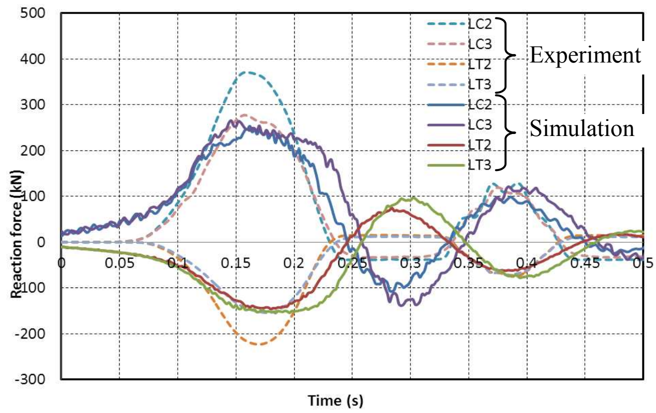

Fig. 3 Reaction force history

5. CONCLUSION

This research concerning rockfall protection fence contributed some technical ideas to numerical computation of impact response on cable net using FE dynamic code. It was also shown that the numerical simulation and the real experiment showed a mostly good fit in impact force, reaction force, natural period and damping. To utilize advantages of simulation more, further investigations of simulation of impact behavior on cable nets with sand packs cushion and cable nets with failures are planning.

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