NUMERICAL MODELING OF ROCKFALL PROTECTION FENCE WITH SAND-PACK CUSHION

Kanazawa University, Graduate school of Nature Science and Technology, Student Member ○Tam Sy HO
Kanazawa University, Faculty of Environmental Design, Member Hiroshi MASUYA
Protec Engineering, Technology Development Department, Member Yoichi NISHITA

1. INTRODUCTION

Recently, numerical researches on flexible fences have been obtained big advance in improving modeling tool as well as providing better understand on dynamic behaviors (Gentilini C. et al., 2012 and Gottardi G. et al., 2010). It is clear that the fences used in these researches were designed with deformable aluminium tube or friction energy dissipating devices. The idea of using sand cushion for wire net was first proposed by Nishita et al. (2011) through series of experiments. However, to design rockfall protection structures with respect to performance-based design, numerical approaches for this complex structure is very important and useful. Sand is granular material, therefore discrete element method (DEM) is thought one of the most appropriate tools. However, finite element method (FEM) has seemingly obtained useful achievements not only for general structures but also for flexible structures as like a cable fence. Applying the obtained results of FEM analysis for sand cushions of rockfall protection structures (Ho S. T. et al., 2011), the numerical approach is shown in this study using FEM to simulate impact behaviors of fence with sand-pack cushion subjected to rockfall. The aims of the study are to provide a practical tool for designing the complicated rockfall protection structure and to get better understand about the impact behaviors of the structure. Results of numerical simulation were evaluated through a comparison with those from the experiment.

2. OUTLINE OF EXPERIMENTS

The fence used in experiment involves three cable net panels, four high strength posts, border cables to connect the net to the posts, some steel braces to enhance stability, and many sand-packs covering on the net as shown in Figure 1.. This whole configuration was placed on two reinforced concrete beams with the gap of 3.5 m from the ground. The cable net was woven by 12 mm-diameter cable, and its dimensions were 4×5 m. The fence was subjected to an impact of a 1 ton weight from 7 m height. The shape of the weight was polygonal according to the European technical approval guidelines. The diameter of border cables was 22 mm. The post was a complex structure, combining from a 318.5 mm-outer-diameter steel tube, nineteen 60.5 mm-outer-diameter steel tubes and concrete mortar filled within interspace of outer tube and small tubes. Two load cells were installed in two supports of one post to measure upward and downward reaction forces (named as F_r_UL and F_r_DL). One accelerometer was installed in the center of the weight to measure acceleration. Therefore, impact force (F_{im}) was calculated by multiplying the measured acceleration by the weight mass.

3. NUMERICAL MODELING

Finite element code of LS-DYNA with various usable elements, material, and contact types expected to adopt cable fence structure and sand-pack was selected to simulate the dynamic behavior of the experiment shown above. Elastic material and discrete beam elements were used for all cable components. Elastic behavior based on the relationship of bending moment and curvature and normal beam elements were adopted for the post. The sand block and weight were modeled by 8-nodes solid elements and elastic material property. The braces were modeled by single truss as a representative linear elastic material for steel. Finally, the bag containing the sand was reproduced by 4-nodes shell elements and elastic material. Ends of border cables and supports of the post were fixed, however, connections at mesh joints and between nets and border cables were simulated as friction contacts. The initial drop height was equivalently converted in to an initial velocity and the small remain of drop height for the

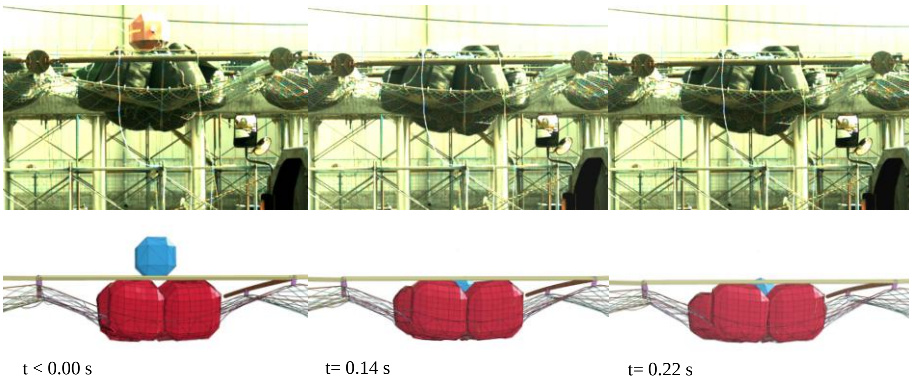

Figure 1 Experimental and numerical deformations of the fence

Keywords: Impact behavior, Protection fence, Numerical modeling, Rockfall, Sand-pack cushion
Contacts: 920-1192 Kanazawa University, Kakuma, Kanazawa, Ishikawa Prefecture TEL 076-234-4603
Email: sytam79@stu.kanazawa-u.ac.jp

sake of saving the calculation time.

4. RESULTS AND DISCUSSIONS

Figures 1 to 3 present a comparison between experimental and numerical results concerning general impact phenomenon, impact load and its impulse. Figure 1 shows a good agreement between experimental and numerical deformations of the fence during impact with three different time-points. A good match can be seen between the maximum values of impact force and history of impulse by impact obtained from experiment and simulation in Figure 2. The experimental and numerical impact histories have the same tendencies, for example the maximal impact force and impact duration, although there are minor scatters at some moments. The relations between impact forces and penetration depth of the weight in Figure 3 indicate that the maximum values of weight displacement into sand-pack are almost the same. Figure 4 shows reaction force histories from the simulation and experiment. The tendencies are almost the same with perfect fit up to about 0.18 s. The periods of reaction forces from both experiment and simulation are similar. However, the differences between experiment and simulation are observed after 0.18 s. For these differences, the yields of outer tubes of the posts at supporting points and plastic deformations after repeated launches enable to be considered the reasons.

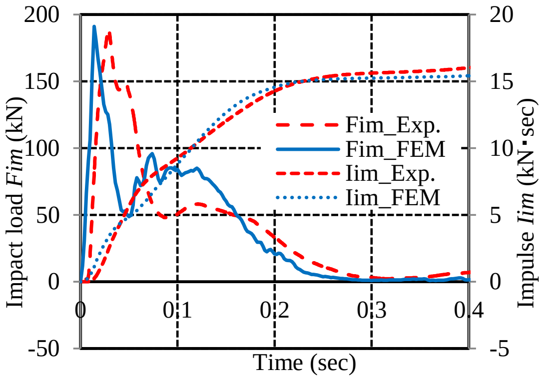

Figure 2. Experimental and numerical histories of impact forces and impulses by impact

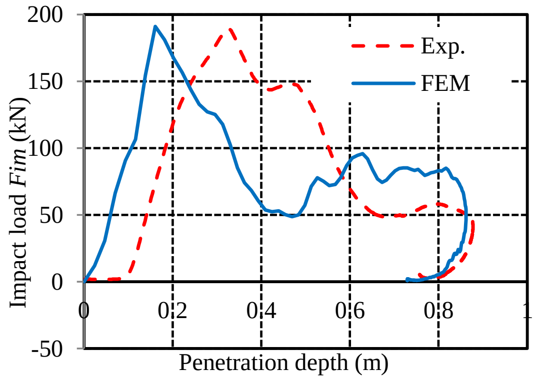

Figure 3. Relationships of impact force and weight penetration depth.

5. CONCLUSION

In this study, it was shown that impact force, impulse, penetration and reaction force can be reproduced by the simulation applying the FEM for the protection fence with sand pack se under impact load. With regards to performance-based design approach, the promising results presented an useful application of FEM for analyzing impact on flexible fence combining with discrete material of sand-packs. This numerical model is continuously developing and applying for further investigation on such the fence with sand-packs cushion.

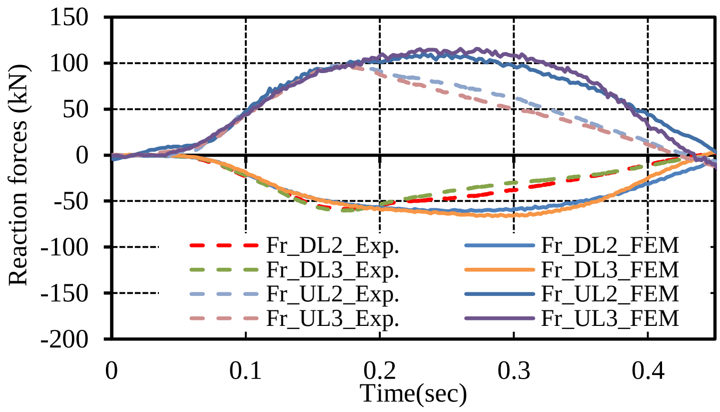

Figure 4. Experimental and numerical reaction forces at supports

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