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Comparison of two DEM modeling of flexible rockfall fences under dynamic impact

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Flexible fences are efficient and cost-effective rockfall protection structures, but their complex response to impact remains difficult to predict. Models based on a discrete element method (DEM) of rock impact on a flexible fence are developed for a better understanding of the dynamic response of the structure under impact. Two of these models are introduced and compared in this paper.

1 CONTEXT

Numerical modeling is increasingly used in order to better understand the behavior of flexible rockfall fences. Impact simulations can be used by manufacturers for the design of their structures prior to full-scale tests, or by public authorities before installing the fences. The high number of existing models prompts interests for the realization of a benchmark of the different approaches in order to identify their comparative advantages, limitations and domains of validity. As a first step in pooling together and compare the existing numerical models, the mechanical response of two rockfall fences models independently developed in the context of the French National project C2ROP are compared against a reference structure and experimental data.

2 MODELS

2.1 Reference Structure

Within the French national project C2ROP, a 300 kJ flexible rockfall fence has been developed. This research prototype results from the collaboration between manufacturers, academic researchers and public authorities and is used as the reference structure in the present study. Several specific tests have been performed on the structural components (ring net, energy dissipating devices) (Olmedo, 2017), as well as instrumented full-scale tests were carried out on the entire structure. A full-scale test with an impact energy of 270 kJ in the ETAG 27 MEL conditions (EOTA, 2012) using a boulder of 750 mm long, a mass of 740 kg and an impact velocity of 27 m/s is used as the reference impact configuration.

2.2 Numerical models

Both models introduced herein are based on a DEM discretization of the individual components. The models are calibrated against identical data from characterization tests on individual components. No back-analysis is performed from the experimental full-scale tests so that differences in the simulation results would only be attributed to the different modeling assumptions. In both models, the anchors are considered as fixed points (boundary conditions) and the energy dissipating devices as two particles linked by a remote interaction. The main differences between the two models lie in the posts, ring net and cable modeling and are summarized in Table 1.

Table 1 : Differences between the models

Component	Model 1	Model 2
Cable / Net link	The cable is modelled by a cylinder which allows a “real” contact. In these conditions it is possible to create the link between the cable and the net by a shackle (Albaba et al., 2017) (Figure 1).	Sliding cable model of Coulibaly et al., (2018). Cables are modeled as a set of ordered nodes. Cable/net link is modeled by integrating a sliding node in the set of nodes and sliding is obtained by swapping material from one side of the sliding node to the other (Figure 2).

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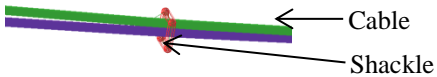

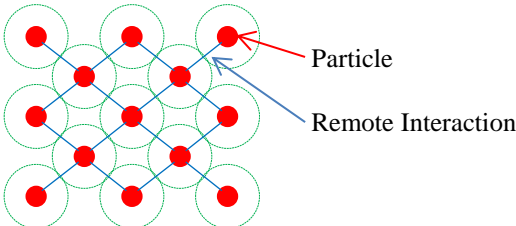
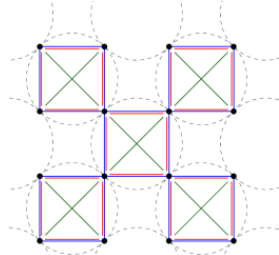
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Component	Model 1	Model 2
	 <p>Figure 1 : Link Net/Cable with shackle</p>	 <p>Figure 2 : Sliding model from Coulibaly et al. (2018)</p>
Ring net	<p>Adaptation of Nicot's 6 contacts rings net model (Nicot et al., 2001) to a 4 contacts rings net. The rings are modelled by a particle located at their center of gravity and the contact between the rings is modelled by a remote interaction (Figure 3). The model is calibrated from an experimental tensile test on a 3x3 rings sample.</p>  <p>Figure 3 : Adaptation of Nicot's model</p>	<p>Ring model of Coulibaly et al. (2017). Individual rings are discretized in their 4 contacts points and assembled. The mechanical behavior of a ring is accounted for by 7 specifically defined remote interactions (Figure 4). The model is calibrated from experimental tensile tests on isolated rings.</p>  <p>Figure 4 : Ring model from Coulibaly et al. (2017).</p>
Posts	Elastic beams	Rigid beams

3 RESULTS/DISCUSSION

On the structure scale, both models provide similar results on both qualitative and quantitative points of view (Figure 5). The most refined model (model 2) is more suitable for local analysis of the mechanical response. The computation time is also slightly advantageous for model 2, compared to model 1, contrary to the development time. Indeed, the model 1 was built with existing models while for the model 2, new sliding and ring models were developed.

4 CONCLUSION

The influence of the differences in the modeling has been illustrated by this exploratory work. The differences observed tend to indicate that the existing numerical models have advantages and limitations that require further investigations. This work is a first step in the realization of a benchmark of the different approaches for the identification their specificities.

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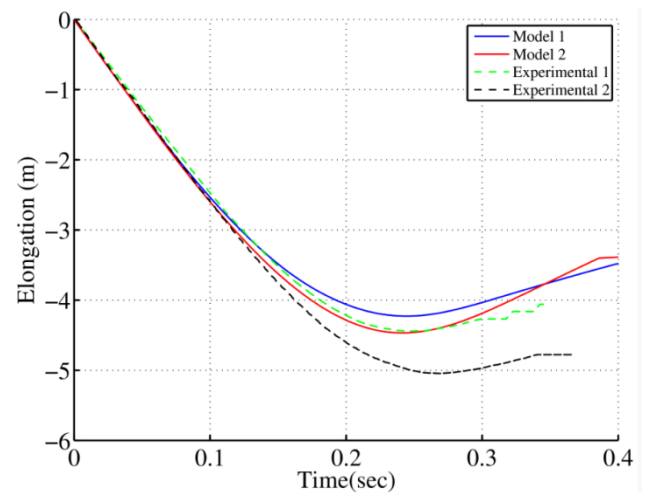


Figure 5 : Elongation of the net versus time for models and experimental tests